ENGINEERING:

An Illustrated Weekly Journal.

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Tenders to be lodged by Ten a.m., 26th September, 1919.
Detailed list, together with Tender Form and Permit to view, can be obtained from the CONTROLLER, D.B.I.E., Charing Cross Embankment Buildings, W.C. 2.

NOTE.—For *Surplus*, the detailed list of Surplus Government Property for sale, apply at the nearest Bookstall or to a local Newsagent (to whom a standing order should be given), compiled by the Director of Publicity, Ministry of Munitions, Whitehall Place, London, S.W.1. Price 3d. A 371

MUNICIPAL COUNCIL OF JOHANNESBURG—CONTRACT 944.

Sealed Tenders, Endorsed

Contract 944, will be received by the TOWN CLERK, Tender Box, Municipal Offices, Johannesburg, not later than Twelve noon, Monday, 1st December, 1919, for EXTENSION OF BY-PRODUCTS PLANT, Municipal Abbattoirs, Newtown. Drawings and documents can be viewed at the Council's London Agents, Messrs. E. W. CARLING & Co., St. Dunstan's Buildings, St. Dunstan's Hill, London, E.C. 3, and copies obtained on deposit of £3 3s. The lowest or any Tender will not necessarily be accepted.
C. S. BURT ANDREWS,
Johannesburg, Town Engineer.
28th July, 1919. A 359

G. R.

MINISTRY OF MUNITIONS.
BY DIRECTION OF THE DISPOSAL BOARD.

Woodworking Machinery,

consisting of the following:—
ONE DOUBLE DIAGONAL FLITCH FRAME, by Johnstone, Hewitson & Wilson. Maximum size of deals up to 11 in. by 3 in. Floor space 3 ft. 6 in. by 21 ft. 4 in. Diameter of flywheel 3 ft. by 4½ in. face. Ref. M.K./7910.
ONE DITTO, by Ransome. Maximum size of deals up to 14 in. by 4 in. Floor space 5 ft. 8 in. by 3 ft. 3 in. Flywheel 3 ft. 6 in. by 9 in. face. Ref. M.K./7911.
ONE STEAM CROSS CUT SAW, by Ransome. Diameter of cylinder about 6 in., stroke 2 ft., working pressure 60 lbs. per sq. in. Floor space 8 ft. by 4 ft. Ref. M.K./7912.
Above lying at Royal Ordnance Factory, Woolwich.
ONE 18 in. CIRCULAR SAW, by Wadkin. Arranged for motor drive, but exclusive of motor. Ref. M.K./6448.
THREE 16 in. CIRCULAR SAWS, by Wadkin, with 4 HP. B.T.H. motor. Ref. M.K./6453, 6450, 6451.
ONE 36 in. BAND SAW, belt drive, fast and loose pulleys, 18 in. by 3½ in. Ref. M.K./6454 A.
ONE MORTISE & BORING STAND, Type A. by A., suitable for attaching to 18 in. Circular Saws. Ref. M.K./6454.
ONE 24 in. CIRCULAR SAW, by Haigh. Belt driven, fast and loose pulleys, 8 in. by 4 in. Ref. M.K./6452.
ONE 9 in. Overhand Type WOOD PLANING MACHINE, by Sagar. Ref. M.K./6634.
Above lying at R.A.F. Stores, Blackwall Lane, Greenwich.
Tenders for above must be received not later than Ten a.m. on 30th September, 1919.
Tender Forms and Permits to view can be obtained on application to the CONTROLLER, D.B. 1 (B.), Charing Cross Embankment Buildings, London, W.C. 2.
NOTE.—For *Surplus*, the Detailed List of Surplus Government Property for Sale, apply at the nearest Bookstall, or to a local Newsagent (to whom a standing order should be given). Compiled by the Director of Publicity, Ministry of Munitions, Whitehall Place, London, S.W. 1. Price 3d. A 180

NOTCHED BAR TESTS.

By DR. W. C. UNWIN.

The mean error.—In discussing the consistency of observations, it has been usual to calculate a quantity termed the "probable error" in the theory of errors of observation. But this calculation is a little laborious, and some years ago Professor Martens pointed out that for practical purposes, a quantity termed the "mean error" differs little from the probable error, and is easier to calculate.

Suppose there are n observations of a quantity, o_1, o_2, o_3 . . . o_n, and let M be the arithmetical mean of these. Then $\Delta_1 = M - o_1$; $\Delta_2 = M - o_2$ . . . $\Delta_n = M - o_n$ are the errors of the observations, or divergencies of individual observations from the mean. The sum $\Delta_1 + \Delta_2 + \ldots \Delta_n$, taken irrespective of sign, divided by n the number of observations, is the "mean error." This may be most conveniently expressed as a percentage of M. Thus, the mean error per cent. is,

$$\Delta\,\% = \frac{100\,\Sigma\,(\Delta_1 + \Delta_2 + \ldots\ldots \Delta_n)}{M}$$

This quantity is a very good test of the consistency of a series of observations. It has been largely used by Martens. The author called attention to this method of discussing test results in an address to the Institution of Mechanical Engineers some years ago. Also Charpy and Thenard, and Major Philpot have used it as a criterion of the trustworthiness of notched bar tests. If the mean error is large, it indicates that there is a cause of variation to be sought.

Variation of results of tests on a given material with a given sized test bar.—The following results are from the paper on Shock Tests, by MM. Charpy and Thenard (Iron and Steel Institute, 1917). Each series consisted of five determinations of the work of rupture, expressed as usual, as $k\,g\,m$ per $c\,m^2$:—

Metal.	Size of Bar.	Work of Rupture.	Mean Error.	Mean Error.
	mm.	kgm./cm.²	kgm./cm.²	per c.
A. Mild steel ..	30×30×160	24·11	0·88	3·6
Mild steel	10×10× 53	16·42	0·20	1·2
J. Semi-hard nickel steel	30×30×160	17·98	0·13	0·7
Semi-hard nickel steel	10×10× 53	12·48	0·34	2·7
P. Hard CrNi steel..	30×30×160	9·98	0·15	1·5
Hard CrNi steel..	10×10× 53	4·76	0·15	3·3
Copper	30×30×160	12·14	0·27	2·2
Copper	10×10× 53	4·95	0·23	4·6

The bars were similar bars, similarly notched. Great care had been taken as to the uniformity of the material. It will be seen that the mean error to be expected, for a given material, and a given size of bar does not exceed 5 per cent. of the mean of the five results. This divergence is, no doubt, mainly due to differences of quality of the material in different bars, in spite of the care taken. In ordinary careful testing, when less trouble has been taken with the material mean errors of 10 per cent. or 15 per cent. occur.

In the British Association Report for 1918, page 17, there is a report of a Committee on Impact Tests. Taking Table VIII., tests are given on 10 × 10 mm. bars, similarly notched and broken in a Charpy machine. Three or four tests were made of each material, and the mean work of rupture and mean error in each series was as follows :—

Material.	Mean Work.	Mean Error.
	kgm. per cm.²	per cent.
Carbon steel	0·835	± 2·4
Carbon steel	0·938	8·2
Carbon steel	0·88	12·5
Carbon steel	1·12	10·6
Carbon steel	7·98	1·5
Gun steel	8·27	9·4
VaCr steel	7·99	1·3
NiCr steel	10·67	2·0
Ni steel	9·64	17·7

Now, if notched-bar tests could always be made on bars of the same dimensions, the work of fracture per $c\,m^2$ of the section at the notch would be a sufficient practical guide to the quality of the material. Good material would give a high relative value, and brittle material a low relative value. But this is not a practical proposition. It is not possible to test different materials in different cases with bars of uniform size. Sizes from 5 × 5 mm. to 30 × 30 mm. are in use. Comparing the results on 30 × 30 mm. and 10 × 10 mm. bars, it is clear that W/a, the work per cm^2, is different for different sized bars, being less as the bars are smaller.

The work of rupture is not proportional to the volume of the bar.—It has been stated that the constant required would be found by dividing the work of rupture by the volume of the bar. In the tests above the volume of the larger bars was, 144 cm^3 and of the smaller 5·33 cm^3. The following table gives the work per cubic centimeter of bar, and the mean error or divergence for each pair of different-sized bars.

Material.	Bar.	Work of Rupture.	Work per Cm³.	Mean.	Mean Error.	Mean Error.
		kgm.				
A ..	30×30×160	108·0	0·75	1·15	0·40	per c. 35·0
	10×10× 53	8·21	1·54			
J ..	30×30×160	81·0	0·56	0·87	0·31	36·0
	10×10× 53	6·24	1·17			
P ..	30×30×160	45·0	0·31	0·38	0·07	18·0
	10×10× 53	2·38	0·45			
Copper ..	30×30×160	55·0	0·38	0·42	0·04	9·5
	10×10× 53	2·47	0·46			

Obviously, the work per cm^2 for two bars of different size is not a constant, and the mean error of the pairs of results is large and variable. The idea that the constant required in reducing the tests must be of the nature of a stress, and, therefore, of the dimensions work divided by volume, involves various assumptions. If the whole volume of the bar is not to be taken, no one has suggested what other volume should be used. The fracture of a notched bar is of the nature of a progressive tear. The area resisting and the distribution of the resisting stress vary in the process. Probably, only a very short length of the bar in the neighbourhood of the fracture is in any appreciable way concerned in the deformation. These considerations throw doubt on the application to this case of the dimensional law.

Tests in the British Association Report.—As a matter of fact, notched bar test bars have been made of various sizes, 30 × 30 mm., 20 × 20 mm, 10 × 10 mm., and 5 × 5 mm. Whether this variety of sizes is necessary or not it is certainly convenient., But the ratio of resistance for different sizes is up to the present undetermined, and tests on bars of differing size cannot be compared. There are very few published tests on bars of different sizes made with the same form of notch and with other conditions so much the same that they are properly comparable. It was, therefore, with much hope that a Report of a Committee of the British Association (1918, page 17) was examined. The object of the Committee was to standardize impact tests; they made tests of a variety of material, the bars of each material were of different sizes from 10 × 10 mm. to 30 × 30 mm.; the notches were of the same form, although the depth of notch did not exactly conform to conditions of similarity. Still, it would be expected that the ratio of the work of rupture for two sizes would be reasonably constant. Perhaps, unfortunately, four different machines were used, a Charpy pendulum and Guillery rotary machine for the 10 × 10 mm. bars, and two Martens drop weight machines for the 20 × 20 mm. and 30 × 30 mm. bars. Still, this should not have made any serious difference. Charpy and Thenard found that results with all three types of machine were very little different. It is not so with the Committee's results. The following table gives the ratios of the $k\,g\,m$ per cm^2, obtained for different materials for each pair of testing machines. Two series, one on steel 1,324, and one on R 31, are excluded as exceptionally anomalous.

These ratios are so different that it is impossible to make anything of them. At any rate, they are so divergent that they cannot be used to determine the law of variation of resistance with size. They are constant neither for one pair of machines nor are the divergencies constant in direction.

Unfortunately, such divergences are not uncommon in records of notched bar tests. No doubt, the Committee's tests were made carefully, but the divergencies are greater than can be explained by differences of quality of different bars. In certain cases it has seemed to the author that there may be a difference in the type of fracture, but this is a guess, and requires confirmation. For one thing, it seems that the possible waste of work, in vibrations of hammer and anvil have not been considered.

Material.	Guillery 10 × 10 Charpy 10 × 10	Martens 30 × 30 Charpy 10 × 10	Martens 30 × 30 Martens 20 × 20
Carbon steel	1·35	0·75	1·92
Carbon steel	2·05	0·85	1·72
Carbon steel	1·43	0·72	1·50
Carbon steel	1·46	0·80	1·50
Gun steel	0·90	1·04	1·12
VaCr steel	1·23	0·33	1·25
NiCr steel	0·59	1·25	1·32
Ni steel	0·46	0·79	1·15

Empirical formula of reduction for notched bar tests.—The only published results on bars of different sizes, with the same form of notch, and made otherwise in the same conditions, known to the author are those of MM. Charpy and Thenard, and it would be difficult to overrate the value of the paper they contributed to the Iron and Steel Institute, 1917. For practical purposes, an empirical formula may be very useful, and it may, at least, indicate the direction in which a more rational formula is to be sought. For practical purposes, we require to deduce from test results a constant characteristic of the material. Obviously, if possible, the constant for different sizes of test bar should be the same, or at least have a constant ratio.

Hitherto, the constant used has been the work of rupture per $c\,m^2$ of section at the bottom of the notch. It was quite well understood that this was an empirical reduction, and that this constant was different for different sizes of test bar. In Charpy and Thenard's paper, page 76, there are tests of four materials, and on 30 × 30 mm. and 10 × 10 mm bars of each. The following table gives the values of the work of rupture W, divided by the area of section a, and the mean error, or mean divergence from the mean for each pair of results. The values of W/a are the means of five individual observations :—

Material.	Size of Bar.	Work of Rupture.	Mean Error.
	mm.	kgm. per cm.²	per cent.
A. Carbon	30×30	24·11	±19·1
Carbon	10×10	16·42	
J. Semi-hard nickel	30×30	17·98	18·0
Semi-hard nickel	10×10	12·48	
P. NiCr steel	30×30	9·98	35·2
NiCr steel	10×10	4·76	
Copper	30×30	12·14	41·5
Copper	10×10	4·95	

Here the errors or divergences from the mean are large and irregular. Only clearly, the work per $c\,m^2$ is larger as the size of the bar is larger. The divergencies, however, are greater than can be attributed to variations of quality of material, and are always in one direction, showing that the formula of reduction is unsuitable.

Let W be the work of rupture in $k\,g\,m$; a the area in $c\,m^2$, b the breadth in $c\,m$; and h the depth in $c\,m$ at the bottom of the notch. It occurred to the author to try whether the quantities

$$\frac{W}{a^{3/4}} \text{ or } \frac{W}{b\,h^{3/2}}$$

would be more constant than $\frac{W}{a}$. The table in the next column gives these quantities for the same materials, as in the table above, and the mean errors of each pair.

It will be seen that for the new values which are not very different from each other, the mean error or mean divergence is reduced to less than half, and what is significant, it is not all in one direction.

So far $W/a^{3/4}$ or $W/bh^{3/2}$ seem about equally approximate.

	Size of Bar.	$\frac{W}{a}$	Mean Error.	$\frac{W}{a^{3/4}}$	Mean Error.	$\frac{W}{b\,h^{3/2}}$	Mean Error.
	mm.		per cent.		per c.		per c.
A	30×30	24·1		16·3		19·6	
			±19·1		±7·9		±8·4
	10×10	16·4		19·2		23·2	
J	30×30	18·0		12·2		14·7	
			18·0		9·0		9·3
	10×10	12·5		14·6		17·7	
P	30×30	10·0		6·8		8·2	
			35·2		9·7		10·1
	10×10	4·8		5·6		6·7	
Copper	30×30	12·1		8·3		10·0	
			41·5		16·9		17·7
	10×10	5·0		5·8		7·0	

The choice of the index in these expressions is somewhat arbitrary, and the index may be expected to vary with the material. It is worth while, therefore, to assume simply W/a^n = constant, and to calculate the index n from Charpy and Thenard's results :—

Material.	Work of Rupture.		n	W/a^n	
	30 × 30 Mm.	10 × 10 Mm.		30 × 30 Mm.	10 × 10 Mm.
A ..	108	8·21	1·17	18·6	18·5
J ..	81	6·24	1·17	13·9	14·0
P ..	45	2·38	1·34	6·0	6·0
Copper ..	55	2·47	1·41	6·6	6·6

The results are too few for a safe generalisation. But it rather looks as if for a very tough material, like copper, the value of n is greater than for steel. Further progress cannot be made till a greater number of careful tests have been made with bars of different sizes, the results of which are as consistent with each other as those of Charpy and Thenard.

It has been remarked that an empirical formula which agreed with a series of experimental results, might give some indication of the direction in which a rational law should be sought. It has been alleged that the constant required in reducing notched bar tests must have the dimensions of work divided by volume. Now, Charpy and Thenard's bars were geometrically similar, and if the above statement is true, the work of rupture should be proportional to the cube of homologous dimensions, or to $a^{1.5}$. According to the tests, this does not seem to be the case.

RECENT MACHINE TOOL DEVELOPMENTS.—No. V.

By JOSEPH HORNER.

Drilling Machine Framings, Bending Stresses.—The framings of drilling machines are subjected to very severe stresses, which are principally due to the pressures required for feeding the drills rather than to those of the peripheral cutting. There is a great difference in the severity of these stresses at the present time, and those which existed previously to the era of high-speed drilling, and of stream lubrication. Much re-designing of elements has been going on with the object of increasing the resistance of framings to the heavy cuts, and to lessen vibration. The rapid work, and the accurate results obtained now would have been impossible in the earlier machines.

There are three elements in the framing of an ordinary single-pillar drilling machine, that are highly sensitive to the feeding pressure—the column, the spindle head, and the table. Each is a cantilever. The upper portion of the column above the table is bent outwards, the spindle head lifts, and the bracket that supports the table is thrust downwards. The greater the vertical range of the machine and the larger the capacity of its "swing," or diameter of work carried, the more severe are these stresses. They are resisted in diverse ways in the numerous designs that are imparted to the great groups of these machines. These are the ordinary upright machines (gear-driven), the high-speed sensitive machines (belt-driven), and the radials (mostly gear-driven, but sometimes with belts for high-speed work). In the sensitive machines the stresses are almost negligible; in the radials they are a maximum. They are also severe in the heavy rigid machines, in which boring of fairly large holes is regularly done in addition to heavy drilling. Again, in the radials when the arm is swivelled to one side, away from the axial line of the base, the stability is lessened, because, when in the diagonal relation, the width of the base affords a less stable resistance to the drill than it does in the longitudinal direction. Further, the heavier a machine is built with a view to resist the stresses imposed on it, the greater is the deadweight, which, especially in the case of the radials, will induce spring and vibration in the arm, plus the spindle head which it carries. Here, again, designers are confronted with the problem of the most judicious distribution of metal. The illustrations following will show in how many ways it is solved. The table and its method of attachment, in the case of the upright pillar machines, is a heavy mass usually unsupported away from its location on the column, but in some of the heaviest machines a supporting screw beneath is provided, as is done in milling machines with knees. But this is not applicable to tables that swivel laterally to move the work about under the drill. When the table is carried directly on the base, or when deep work is supported directly on the base the overhang is avoided. A deep and rigid base is then necessary to avoid spring.

Because of the cantilever action in drilling-machine frames, the metal in most cases is disposed like that in a cantilever beam, or, say, a combination of truncated wedge and cantilever. The sections taper more or less from the areas of support to the outer portions. Columns and pillars are often tapered, or if not, the upper parts are of smaller sections than the lower, or, the thickness of metal is reduced. Brackets for gear shafts have tapered outlines. Table-carrying knees are of rudely triangular, or truncated wedge forms. Radial arms are spread out widely next the column. Hollow box designs are now universally adopted.

Figs. 74 and 75 represent a design of drilling machine frame that in its main aspects was familiar in smaller and larger dimensions alike, in a past that lies within the ken of some of us. A central web deeply ribbed, bossed to receive the drilling spindle and the driving shaft, and bolted down to a shallow baseplate on which the work was carried directly, or if shallow, directly on a table of circular form adjustable along the tee-grooves. Two designs have been branched off from this—the bench

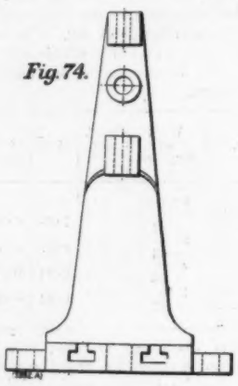


Fig. 74.

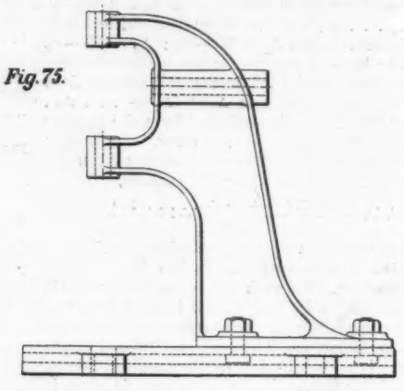


Fig. 75.

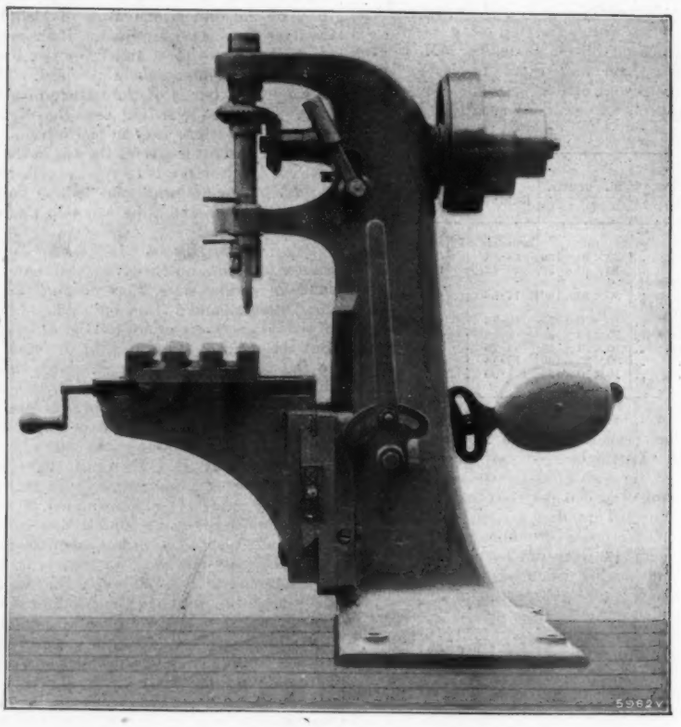


FIG. 76.—WHITWORTH SMALL BENCH DRILLING MACHINE, 1868.

RECENT MACHINE TOOL DEVELOPMENTS.

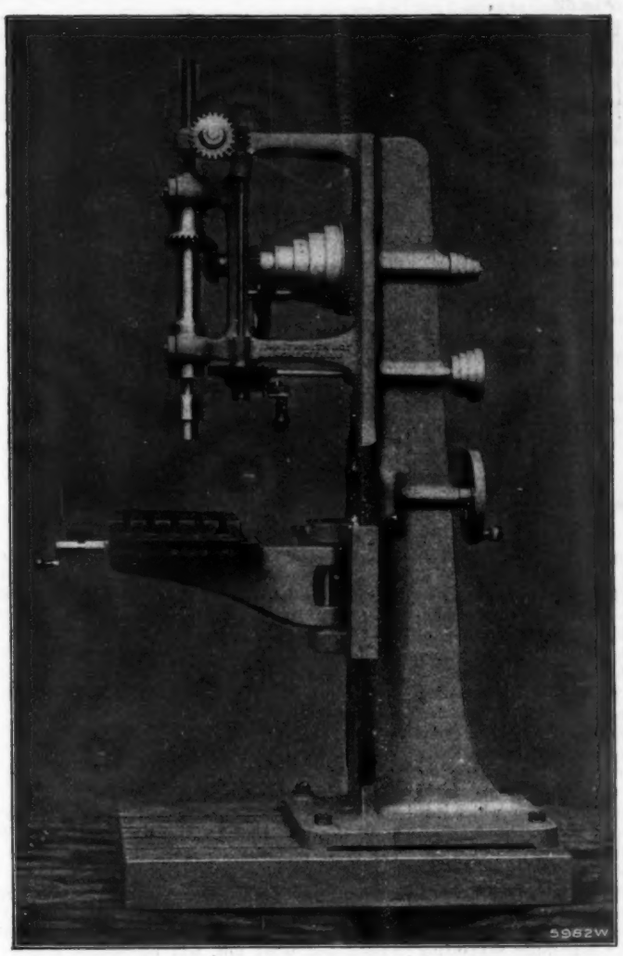


FIG. 77. WHITWORTH DRILLING MACHINE, 1866.

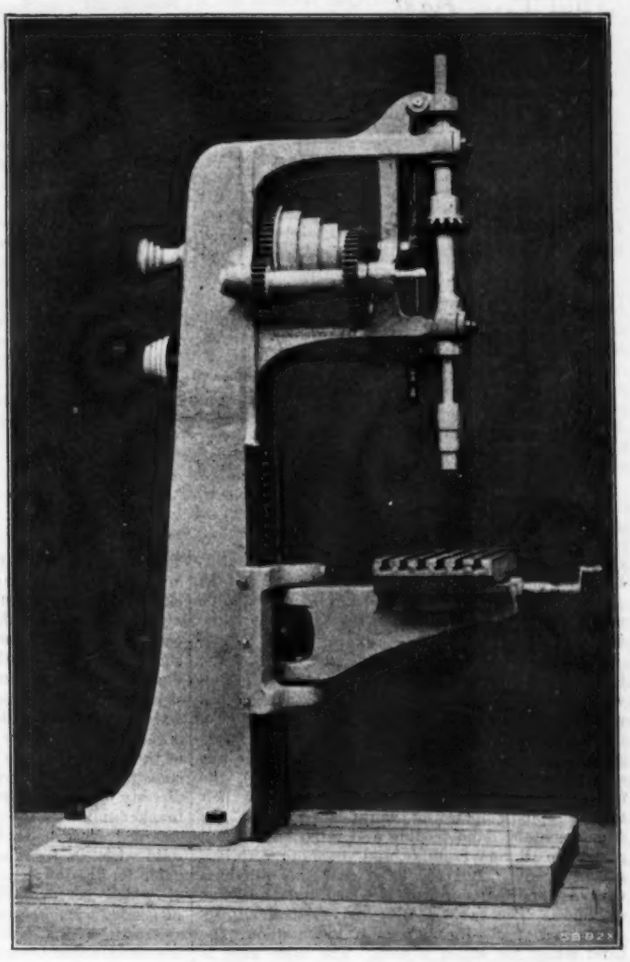
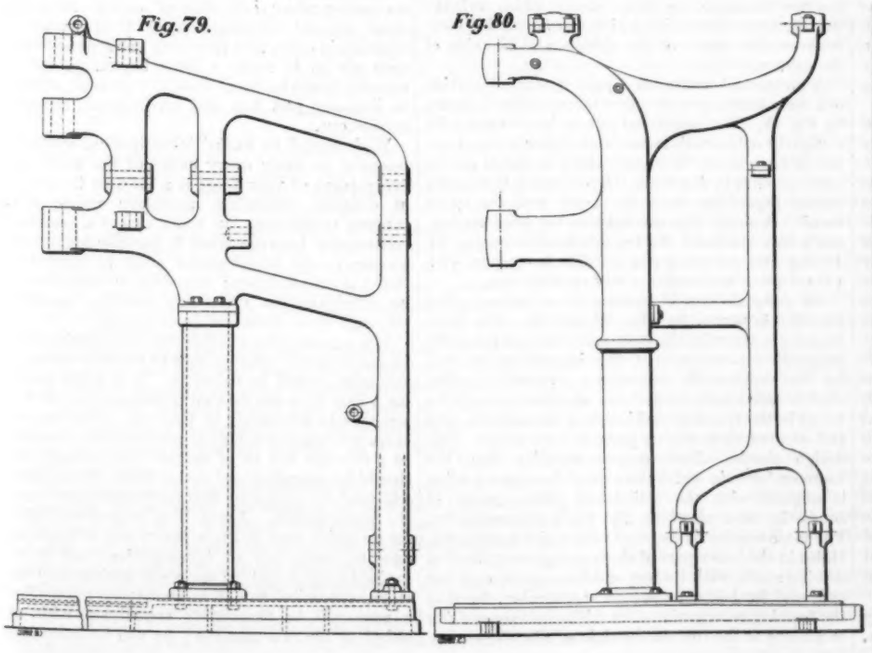


FIG. 78. WHITWORTH DRILLING MACHINE, 1867.



machine, and the various pillar machines bolted to the floor, but all now, and for a long time past, with boxed framings.

Early Whitworth Machines.—The three photographs, Figs. 76, 77 and 78, should possess an interest in connection with the present subject, since they represent transitional forms, built in the sixties by the original Whitworth firm, when Mr. (afterwards Sir Joseph) was the inventive genius at Openshaw, Manchester. They show improvements on then existing designs, and the persistence of early models, notwithstanding the numerous modifications that have been made in details. It is not easy now to separate entirely the originals from the variations. Whitworth was no copyist. He not only invented *ab initio*, but he stamped the individuality of his mechanical genius on every tool made in his shops, even though the archetypal model might have been pre-existent.

Fig. 76 illustrates a small bench drilling machine, as made in 1868. It includes novelties not found in machines of that date. The spindle was driven by a three-speed cone pulley and bevel gears (the only method of power driving then employed). the drive to the spindle was disconnected instantly by a clutch and lever, and the lever was weighted to prevent accidental disengagement. The work-table was provided with compound movements, giving a vertical adjustment, and feed on the face of the frame, a cross-adjustment of the knee on the saddle, and a transverse or radial movement of the work-table on the knee. The vertical feed was effected by the long lever seen in front. The

RECENT MACHINE TOOL DEVELOPMENTS.

Fig. 81.

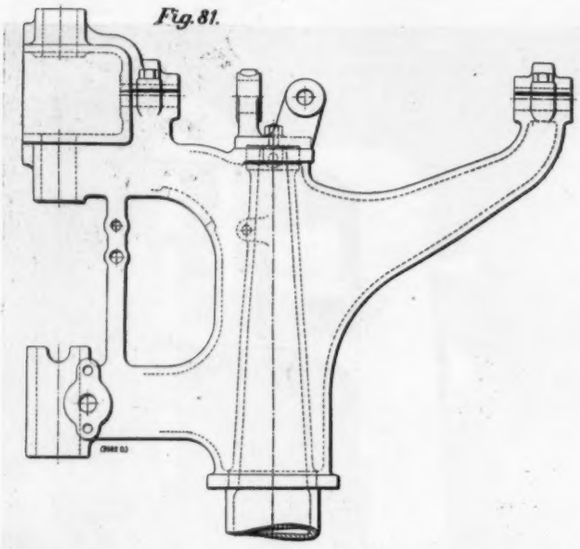


Fig. 82.

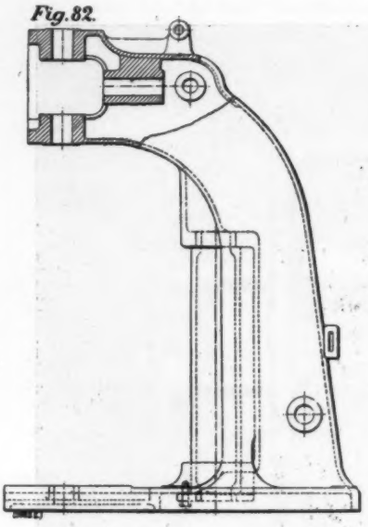
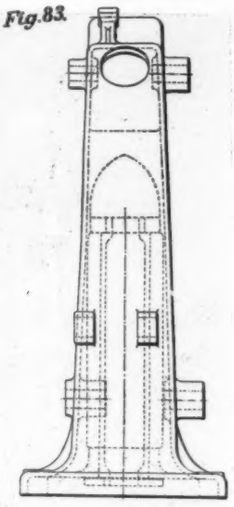


Fig. 83.



elliptical weight seen at the right-hand counterbalanced the weight of the table, knee and saddle. An adjustable gauge seen in front of the spindle regulated the height to which the table was to be fed.

Fig. 77 goes back a little farther, to 1866. The framing is not boxed, but the metal is thicker than was usual in plated and ribbed structures of the period. Machines like this were very familiar even until recently. The stepped belt cones, back-geared (in this instance, the back gear spindle was slid endwise into, and out of engagement), the feed to the drill, transmitted at four rates by belt to the spindle-operating worm gears, with the supplementary hand feeding and rapid adjustment gears, are all very familiar, and yet more than half a century old. But the hand gear was provided with a handle instead of a wheel, put on later machines. The table saddle had vertical adjustment—not feed—through rack and pinion, the hand wheel for which is seen. The table knee is hinged to be swung aside when deep articles have to be stood on the baseplate, a feature perpetuated in many present-day designs.

Fig. 78 is a machine made in 1867—only one year later. But this has a boxed framing, and the back gears are thrown in and out of mesh with an eccentric motion. The table is fitted similarly and its saddle and hinged knee. The elevating rack and pinion are visible here.

Typical Pillar Machines.—Fig. 79 shows a boxed framing long in use, and retained for a good many heavy machines of self-contained pillar design. The leg that carries the knee for the work table is cylindrical and cast separately from the main framing, to permit of its being turned. The table is adjusted vertically on this with worm and rack and pinion, and clamped at any height, or at any plan angle. The frame (boxed), is very rigid. It is divided into pockets at the top. The one to the right receives the cone pulleys for the speed gears, with the back gear spindle, thrown in and out eccentrically. The smaller opening to the left has the upper feed cones. All the shaft and the drill spindle bosses are shown cast solidly with the framing. The framing and the cylindrical column as one are bolted to the baseplate, which has tee-grooves to receive hold-down bolts for the attachment of deep articles when the table is swung aside. The belt-driving pulleys—the fast and loose—and the cones, are carried just above the base. A shaft boss in the right-hand leg is flanked by these two sets of pulleys, and a separate bracket bolted on the baseplate receives the opposite end of the shaft.

Fig. 80, in its main outlines is an extremely popular design of framing, both here and in America. The upper and lower cone pulley shaft brackets are connected and greatly stiffened with a pillar of elliptical cross-section. This is further united at about the centre with an offset piece to the main column, so putting both pillars into the condition of short columns, with increased rigidity. Any tendency of the main column to bend under the stress of heavy feeding is resisted by the strutting action of the rear pillar, and the risk of vibration is lessened. Stability is favoured by the arching of the metal over the space occupied by the lower cone pulleys. The weight of the top pulleys lies directly over the strut. The boss of the table bracket embraces the circular column, to which it is clamped with bolts in split lugs. The bracket, solid with the front upright member, receives the guide for the lower part of the spindle, the weight of which is counterbalanced, the weight being suspended within the column. The same machines are made with a head that slides on the column face and is adjusted through a large range, supporting the spindle close to the work. This example is from a machine by Messrs. F. Pollard and Co., Limited, of Leicester. The back pillar is fitted only to the heavier framings—to those above 20-in. swing—that is, twice the radius which can be carried clear between the centre of the spindle and the side of the column.

A method of fitting the upper bracketed portion of a main framing to the lower turned pillar is shown by Fig. 81. The cylindrical column is extended with a slightly reduced diameter, and thence tapered upwards to receive the head which is bored at the extreme ends to fit over it. The column is thus easily turned separately from the head, and the latter bored. A single big core lightens the head casting, and a core takes out the top left-hand recess for the driving and reversing gears. This is covered with a front plate and makes a stiff enclosed box.

An unusual form of framing for a vertical pillar machine is shown by Figs. 82 and 83. The main framing is cast with the base, parts that are generally prepared separately, but the supporting bracket for the work-table embraces a cylindrical pillar that is fitted with turned end shoulders into holes bored in the framing, and inserted through the base and secured there with a plate and set screw. This design should afford greater stability than the common form, in which the axis of the upper portion is aligned with the cylindrical pillar, except of course in cases of which Fig. 80 is representative. The table bracket is elevated with a pinion and rack. Holes in the lower part of the framing carry the first driving shaft, with its fast and loose pulleys at one end, and the belt cone pulleys at the other, flanking the framing on opposite sides. The belt cones drive to pulleys at the top, on the right of Fig. 83, whence through worm gear and bevels a box of spindle feed gears is driven enclosed within the head of the framing, at the right-hand of Fig. 82. This design is by the Britannia Engineering Company, Limited. The foregoing all relate to machine framings in which the drilling spindle is driven through toothed gears. The belt-driven sensitive machines came much later, and they now include a great variety of examples.

WORKS' INVESTIGATION.

By HENRY ATKINSON.

OWING to the cessation of hostilities a great many firms are reverting to their pre-war industries. The great difference between the manufacture of war and peace material and the installation of machinery for war purposes—machinery which may now be more or less useless—together with the alteration of methods, costing systems, labour conditions and what not, will necessitate a general overhauling and investigation before a clean restart can be made. This is the practical side of reconstruction. Almost all firms, large or small, no matter what their class of manufactures, need some general investigation of their works and methods in order that they may know what position they are in to make a fresh beginning, but frequently it will be found that there is some difficulty in knowing just how this investigation should be carried out.

With regard to works' investigation, while it is essential to study every detail of the works from every point of view there is a limit to the amount of detailed recording necessary under actual running conditions. In order to get a reasonable relationship between what is possible and what is necessary, the investigation must be carried out to the minutest detail; unnecessary items can then be eliminated in organising working conditions although these items will be on record.

It is a moot point whether the investigation should be made by the existing staff or whether an outside specialist should be called in. It is quite possible for a firm to make its own investigation, but there are certain difficulties in the way. For instance, there is frequently a bias in one direction or another, or a director will be of opinion that certain goods should be manufactured rather than others, and he will tend to emphasise this particular point during the investigation. Again, it is frequently difficult for an inside man to know just where to begin and how to carry out an investigation, and it will probably be found to be more satisfactory and more economical to call in an outside man. Such a man will be thoroughly acquainted with the object of the investigation; he will be quite inde-

pendent in his conclusions; he will take an all-round view of the situation; he will go into detail which would probably be neglected by a man on the staff; there will be no jealousies, which would probably arise if an inside man had to examine closely into the details of the work of other members of the staff; the whole investigation will be made more quickly, more easily and more completely, as well as more economically.

If an outside man is called in he should be looked on as a help and not a critic. He is not there to find fault but to bring a scientific training to bear upon the organisation and to improve it where possible. This cannot be done by fault finding or by captious criticism. It is by practical, helpful suggestion and by discovering the weak points in the organisation that the investigator will justify himself.

On the other hand many firms will not tolerate an outsider coming in and investigating all the details of their plant and methods. There may be certain special appliances or methods or processes which are secret or which they do not desire to be closely examined. And apart from this, there is the idea that a firm knows its own business best, though this is sometimes a fallacy. These notes are written in the hope that they may prove suggestive to any firm making its own investigation.

Every firm is possessed of an inventory of some kind, usually this has been got out for insurance purposes if for no other reason. Although this inventory may be more or less out of date, it could probably form a convenient basis for making a complete investigation into the existing state of the plant. Such a revised inventory should not absorb much time. If no such inventory has been made or if it be considered that existing inventories are not sufficiently comprehensive, or if they are not now considered convenient for the purpose, an inventory by means of "plant cards" would be suitable for almost any kind of works. Such cards should be designed for each individual works and the annexed example shows the lines on which this may be done, the illustration being an actual card which is in use in several factories. It is practically self-explanatory but necessitates a series of symbols for the departments and for the plant. The most convenient size of card is 8 in. by 5 in.

Particulars of size, capacity, and production, are all necessary; the size being the actual dimensions of the plant; the capacity being the maximum size or quantity of material which can be placed or treated in the plant at one time; and the production being the output of finished material in a given number of hours.

The adoption of a system of symbols will be found extremely useful where not already in existence. The symbol could be a number or a letter. Each department, each type of machine or plant, and each individual machine or item of plant could all be numbered serially, in which case the figures on the card would read for instance:—

Department 1, machine symbol 3, serial No. 5.

This means lathe No. 5 in the Turning Department, assuming that the Turning Department is Department No. 1, lathes are indicated by machine symbol 3 (boring machines may be 1, drilling machines 2, shaping machines 4, and so on) while the serial No. 5 refers to the individual machine. The division could be carried further by dividing lathes into engine lathes, screw-cutting lathes, and so forth, as there is no limit to serial numbering unless provision has to be made for the insertion of new types of machines, in which case gaps must be left in the numbering. When the symbols take the form of letters the mnemonic system is useful. In such case usually two letters are necessary. For instance:—TU will be the Turning Department, FI the Fitting Department, SM the Smelting Department, FU the Furnace Department, PD the Packing Department, AS the Assembling Department. By adopting two letters a considerable number of symbols may be used without confusion. On the other hand letters may be used without reference to the work carried on in the department, in which case they would run alphabetically. Individual machines or plant in every case would be indicated numerically.

When the plant cards are being made out the symbols should be made prominent in some manner —for instance, painted—on the machine or plant itself. This is not only useful for inventory or valuation purposes, but it is also extremely useful for costing purposes. When a machine needs repair this symbol is written on the time card and when the card is filled in with the man's time there can be no mistake in allocating the cost to the right machine. Further, the machine number on the operator's time card can be checked with that on the machine. This symbol is also written on the stores order card when withdrawing stores for repair purposes.

PLANT CARD.

Date: *July 10th, 1919.* *Card No. 256.*
Firm: *Johnson & Wadmore, Ltd.*
Address: *Hudderston.* Dept.: *Turning.* Symbol: *T. U.*

Classification of Plant: *Lathe.*
Plant or Machine Symbol and No.: *La.* 17.
Maker: *Burnell and Co., Ltd., Tudor Street, Rochdale.*
Date of Installation: *1919.*
Purpose: *Heavy turning, especially gun work.*
Type: *Screw cutting, taper turning, surfacing.*
Size: *20-in. centres.*
Capacity: *Maximum diameter 32 in., maximum length 26 ft.*
Production:
Space alotted in square yards: Plant, *20* Floor, *50* Storage, — Yard, —
Motive Power: *Electric Motor.* B.H.P. required: *30/35.*
Particulars of Drive: *Geared from variable speed motor mounted on lathe.*
Speeds:—Driver, r.p.m., *270/1080* Machine, r.p.m., *3/192.*

NOTE.—*Two tool carriages.*
Special motor, 5 H.P., for rapid traverse.
Weight, 25 tons.

The value of the plant can be put on the plant card together with the annual amount of depreciation. The hourly overhead cost of the plant when running and when idle can also be indicated and in making out costs this can be transferred to the cost card. The advantage of this is that the plant card is a permanent record whereas costs are running expenses and cost cards are filed away each month. The class of work which may be done on each machine should be recorded in order that the capacity of the machine for certain work may be known when estimating. Sometimes the necessity of altering machinery to suit a special job makes a considerable reduction in the profit.

With a card such as this, the investigation of plant is not a difficult or lengthy piece of work. The value of the result far exceeds the cost of the investigation, and the cards form a permanent record.

The layout of plant is a very important matter. This is so well known that it is almost trite to mention it, yet there are many works which, upon examination, create a feeling of despair in the investigator, and the expense of transport, transmission, power, &c., are out of all proportion to the total manufacturing cost. Of course, it is easy to say things must be altered, but expense often stands in the way. Where possible, however, it is better to face the expense in order to reap continual benefits afterwards.

Large scale plans should be made and all machines indicated. The layout of the machines should be so arranged that the work flows easily through the factories, dead-ends being avoided, and the relation of the different shops should be such that the progressive stages of manufacture should take place in consecutive shops and not zig-zag all over the works. In erecting new works this is practically always done and old works should be rearranged with this object. It is frequently difficult to rearrange the internal layout of an old works, but where this is possible it should be planned so that girders and joists are arranged to accommodate standard countershafts, which enable machinery and countershafts to be removed and re-erected quickly and inexpensively. There is a great economy in standardising materials for millwrighting both in first and running costs and in the small quantity of stores which it is necessary to carry.

The investigation should include the condition of the plant relative to its original cost and it should be valued accordingly. Estimates of what is necessary to repair the plant and put it in good condition can be made where plant needs repair. The question of scrapping plant will, of course, receive serious attention. The condition of plant has an important bearing on manufacturing cost, and if finances will allow of scrapping machinery and plant this should be done without hesitation where machines are considered to be inferior or obsolete.

The importance of standardising wherever possible should be kept in mind because of the great saving in tools and fittings, in repairs, in the stocks of spares which need to be held, in quickness in getting delivery of parts. Again, accurate comparisons of machinery may be made when the machines are standardised. In the event of a special appliance (say a jig for a special job) being only adapted to one machine, it may be necessary to take a job out of the machine or wait until it is finished before starting on the job for which the special appliance was made, whereas if several machines are standard the special appliance may be used on any of them. Standardisation will only apply, as a rule, to factories where there is a sufficient quantity of work to employ more than one machine of the same type.

It is surprising how little attention is paid to transport facilities in many factories, and this is one of the items where a good deal of economy can be exercised in nearly every works. At the same time it is frequently difficult to decide just what form of transport should be installed. There is no doubt that overhead is much superior to ground transport. When materials can be carried overhead the clear run which is available means a great saving of time. But the drawback to overhead travelling is its cost both in installation and running. Where there is a great amount of traffic, overhead transport will be economical, but where transport is more or less casual or intermittent, it will be found to be very expensive because the installation is costly and it means the attention of a skilled man who may be idle for a considerable part of his time.

Within the shop the overhead travelling crane is one of the most useful methods of transport because of its flexibility; it can pick up anything anywhere and put it down anywhere. When materials have to be conveyed from one shop to another then a runway or telpher may be used. If either crane or runway are considered to be too expensive then ground transport must be adopted. Electric tractors are extremely useful and do not require very skilful handling; they need a fairly even floor surface and are, perhaps, used to the best advantage on rails, though this limits their mobility. Hand bogies and trolleys are the commonest forms of transport appliances. For small work which can be packed in crates and cases, or in boxes which are of standard size, lifting trolleys are extremely useful as they save a good deal of heavy handling. In yard work the question of horse haulage compared with other forms may seem at first sight antiquated, but in practice it is found that horse haulage is frequently cheaper than any other form for heavy loads, railway wagons, and in confined situations where mechanical transport is practically impossible.

Storekeeping is another important item in connection with works investigation. Very great losses can occur through inefficient storekeeping and the general principle of having a central stores for the receipt of all material coming in for maintenance

purposes, while branch stores, if necessary, for giving out material, will be found to eliminate a good deal of waste. This is not always convenient, but in most shops something of the kind can be adopted. To avoid too much cartage, material can be sent direct to the branch stores after being checked through the central stores.

It need hardly be said that stores should never be given out except on a requisition showing the job number, such requisition to be signed by a responsible person. Duplicates of the requisition should be sent to the cost office for costing the work. The checking of stores should be so arranged that the store record always shows the exact amount of material in stock. There should be an ordering level for all stores so that immediately they become depleted to the ordering level an order will be sent through to the purchase department by the storekeeper. These things are simply arranged and easily carried out and have proved very satisfactory in practice.

Material for manufacture will, of course, be dealt with somewhat differently, stores of this class depending on the nature and amount of finished material of different kinds produced by the works. An intimate knowledge of the conditions is necessary before quantities can be determined, but the principle of an economical stores level should always be in mind and this is closely related to buying and to market fluctuations.

Stores should be convenient to the work, easily accessible and so arranged that any article may be found immediately. Stores of material for manufacture should be so organised that the departmental stores are replenished regularly and the machines should never be kept waiting for material. Identification marks may be put on the material in cases where there are different qualities of the same size, such as different qualities of steel rods and bars.

The routing of the work should be planned so as to allow of a natural progressive flow of work through the shops. All materials necessary for a job should be entered on a bill of material and sent to the stores, and if necessary, the purchase department. A progress sheet should be made out in order that the material may be ready to hand at the correct time and place. Routing, or planning, is a highly important factor in efficient organisation.

Costing is a matter which needs careful investigation especially in view of the recent increases of wages and cost of materials which will be high for some time and will probably be subject to considerable fluctuations. The object of costing is often misunderstood. An absolutely accurate cost can rarely be obtained because there are certain expenses which cannot be accurately proportioned to each individual job. In costing, all that is necessary is an accurate record of labour, materials used, maintenance, power, and such items, and an approximate allocation of overhead expenses to each job. An *approximately* accurate cost can then be obtained, which is extremely useful for estimating purposes, and also for discovering which machines and plant are the most profitable.

There are three kinds of costs—machine cost, works' cost, and complete cost. In the first case the cost consists of the running expenses of the machine, namely, labour, power, repairs, maintenance, &c. In the second case there must be added interest, depreciation, rent, light, heat, and overhead works' executive expenses. In the third case there must be added the general overhead expenses or establishment charges. The overhead expenses for each machine will be a fixed charge which usually remains the same when once it has been determined, unless there is an alteration such as a general increase in administrative costs. There will be a difference in the works' cost when a machine is running and when it is idle, but these items once determined will be fixed. The running cost will be the actual cost according to the time card, the cost of maintenance, and so on; this cost should be ascertained quite separately from the cost of the material, this latter cost being added as a separate item.

In connection with plant and machinery there is one important matter which is frequently overlooked, namely, the cost of plant when idle. This can be easily ascertained but it is not often considered, and such a cost very rarely appears in the books although it is quite essential if an accurate cost of work is to be obtained. It gives quite a false cost of manufacture if the whole of the works' expenses are debited to production when only about half the number of machines are running. The idle cost must be debited to a works' loss account, and by so doing the real cost of production may be ascertained and the loss due to idle plant recorded and fully appreciated. In some cases a machine is required for only a fortnight or so in the whole year. In such an extreme instance the work done on the machine should bear the cost of idle time for the rest of the year if the machine is to be profitable. It is true that the cost of the completely finished manufactured article will admit of this non-working period, but the machine chart will show idle time, which should be marked in red, and this will draw attention to machines which are not productive, and an endeavour will be made to find work for them. In estimating, all factors must bear upon the determination of prices, and this separation into working and idle time is only for purposes of accurate internal costing. Other factors in relation to cost cannot be dealt with in a general review of works investigation, but it may be stated that the principal factors affecting prices are buying, selling, manufacturing cost, and profit, and with skilful management the first three factors should be run on profitable lines independently of each other.

Accurate time-booking is essential to accurate costing. The method of clocking on and off by means of time cards is now the general practice, though scraps of paper and bits of wood rubbed over with chalk may still be found, while in some cases no check at all is made on the time of the worker. Time cards should be used for every job if at all possible. Where the worker is on short jobs or where the works are of large area much time may be wasted in journeying to and from the clock. In such cases it is usual for the foreman to write the time on the time card, but clocking is much more satisfactory.

There are different methods of checking the time on a job, such, for instance, as using one card for each job or using one card for all jobs. In each case there would be stampings for "on" and "off," but in the second case the particulars of the job would have to be written on the card at each clocking on; it depends on local conditions which is the more suitable. Where a worker is always on the same job his attendance card is the job card also.

It is, perhaps, a matter of opinion which make of clock to use and the catalogues of the different makers should be consulted. The "International" and the "Gledhill-Brook" are good, and the latter is comprehensive in its application to different methods of time-booking. The pocket time recording watch which can be carried about by the foreman is still to be invented, but that the difficulties are not insuperable is shown by the fact that small time and date stamping desk clocks have been in use for many years.

With accurate time-booking, accurate costs of repairs and maintenance, approximately accurate proportioning of overhead expenses to machine hours, and accurate booking of transport and subsidiary services, the costing of work, and hence, of estimating, becomes easy and efficient. These accurate records also make it possible to judge the relative value of different machines and plant, to appreciate the losses on idle plant, to check the relation between productive and non-productive work, and to grasp the whole of the details of production from the raw material to the finished article.

When the investigation is complete, the facts obtained, together with the suggestions that have been made will enable the management to form a correct estimate of the capabilities of the plant and of what re-arrangements and expenditure are necessary to put it into first-class order. The records made will also form a basis for organising the works on economical lines. The simplicity of such an investigation is obvious, yet it is quite the exception to find it carried out. The essential things are, to be sure that the information is correct and that the records are presented in such a form as may be easily and quickly understood.

ACCOUNT OF THE BRITISH TANKS USED IN THE WAR.*

By Sir EUSTACE H. TENNYSON D'EYNCOURT, K.C.B.
Director of Naval Construction, the Admiralty.

WHEN I was invited to read a paper on the subject, of Tanks at this meeting of the British Association, I had to obtain the permission of the War Office, as all information on tanks had during the war been kept secret, and it is therefore with their sanction that I am able to comply with the request.

As the subject is a new one, and not much has been published about it hitherto, I thought that before coming to the more detailed technical portion of the paper, it would be of general interest to give some account of the early history and the circumstances leading up to the use of tanks in the Great War.

It has often been asked, Who invented the tanks? I do not think it is possible to say that any one man was the inventor. The original idea of the tanks is very old. When one considers that perhaps the main consideration is that of bringing up fighting men into the thick of the fray, whilst giving them a certain amount of protection against enemy missiles, and placing them in a position of advantage relatively to the foe, at the same time carrying with them such weapons of offence as is possible, this idea was embodied in the war chariots of the ancients—Greeks, Romans, Britons and other nations, until we come down to feudal times, when perhaps the simplest form of tank was adopted and probably first used in this country at the Battle of Hastings. I refer to the one-horse power, one-man tank—namely, the knight in armour. He embodied the tank idea pretty fully. He was able to move at a fairly rapid rate over ordinary ground, supported by his attendant infantry. He was fairly proof against arrows and other missiles, and he could deal blows at the enemy from his position of advantage; or in company with other "tanks," he could charge the enemy with the enormous advantage of united weight and moral superiority over the less well-protected antagonist. His weakest point was probably his motive power, or horse, and if this was disabled, he was of comparatively little use, unless he became a rallying point for his infantry, just as our own disabled tanks have frequently been.

There were many other forms of tanks in old days. The Chinese and other nations had protected chariots. Later, the great Italian, Leonardo da Vinci, wrote in 1482 to the Duke Sforza to say: "I am building secure and covered chariots which are invulnerable, and when they advance with their gun into the midst of the foe, even the largest enemy masses retreat, and behind them the foot-soldiers can follow in safety and without opposition."

Voltaire also suggested similar machines in the eighteenth century. As late as 1855 a certain James Cowen took out provisional protection for a locomotive land battery, fitted with scythes to mow down infantry, and urged Lord Palmerston to adopt his device. Apparently his proposals were "turned down."

The above instances show, I think, that the tank idea is not a new one; but, coming to modern warfare, the idea appears to have remained dormant in recent years until the commencement of the Great War, when a good many people began to think that something of the kind might be tried with good effect. This was especially the case in the last months of 1914, when it became pretty evident that every day the line of enemy defences was becoming stronger and more fortified with machine guns, innumerable lines of trenches, &c. In fact, the enemy had dug themselves in very securely and a war of position had apparently set in. The problem, therefore, was how to break through with the minimum sacrifice of life and with the best prospects of being able to continue and make effective any advance already achieved after a breakthrough.

This led a good many people to think that some sort of landship, akin to a floating war vessel should be devised for the purpose, and various propositions were put forward.

The only experience in 1914 of anything approaching this type of warfare, utilising mobile carriers of troops or armament, was that gained with armoured trains on railways, or armoured cars. The former were, of course useless for an advance over anything but an already prepared railroad; the latter required an ordinary road of more or less even surface, as does a motor car. The armoured cars, however, which had been supplied to the Royal Naval Air Service, had already proved their utility, and had done quite good work, in Belgium especially. This was made so clear to the minds of the Naval Air Service officers who had used them, that they became strong advocates of an improved landship, and Major Hetherington, and other officers of the Air Service, spoke to Mr. Churchill, who was then First Lord of the Admiralty, on the subject. He took up the idea most enthusiastically, and with great prescience decided, if possible, to produce some landships. He took the initiative in the matter, and with characteristic forethought allocated a sum of money for the purpose, and decided to make a start on practical lines. Strong representations of the advantages of such a course had also been made by Colonel (now Sir) M. Hankey, and by Colonel (now General) Sir E. Swinton, who has throughout been an enthusiastic advocate of tanks. Certain definite proposals for the type of machine required were made to Mr. Churchill by Major Hetherington, but these proposals, whilst very ambitious, could hardly be regarded as they stood as a practical engineering proposition.

Mr. Churchill, recognising that probably the idea could

* Paper read before Section G of the British Association, at Bournemouth, September 10, 1919.

be developed by the technical officers at the Admiralty, as was frequently the case in the matter of new warship designs, sent for me, as Chief Naval Constructor and Technical Adviser to the Admiralty, and asked me what I thought of the scheme. Lord Fisher, who was then First Sea Lord, also advocated the whole matter being referred to me. I had always considered that there were great possibilities for a landship, and after considering the matter, I agreed to form a committee, and undertook the design and production of a certain number of landships, for which Mr. Churchill accordingly made me responsible, allowing a considerable sum for experimental work. The committee started at once, and we decided to investigate two types:—

(1) A large wheeled tractor type; and

(2) A caterpillar tractor type.

The order for the wheeled type was, after some consultation, placed with Messrs. Foster of Lincoln, Mr.—now Sir William—Tritton undertaking the development and construction of 12 of these. At the same time, Colonel Crompton, who had been engaged by the Admiralty to join the Landship Committee, was to assist in developing the design of the caterpillar type, and it was decided to try to utilise the Diplock caterpillar type of tractor, of which a sample had been obtained and shown to the First Lord.

Whilst these proposals were being developed, it was decided at the same time to obtain some tractors of the agricultural type from the U.S.A. for experimental purposes, and as soon as they were prepared, trials were made with two of these linked together, the idea being that in this manner one would help the other over trenches or other obstacles. This experiment, though it gave valuable information, was not successful. It was found practically impossible to get a suitable coupling of strength sufficient to stand the strains to which it was subjected, and there were other objections and difficulties which made me decide to abandon the idea of coupling two machines together.

The design for the big-wheel machines ordered from Messrs. Foster's required 15-ft. wheels in order to get over the rough ground, but a model which was made showed that the machine was going to be too high and too conspicuous an object. After a time, therefore, this proposal was abandoned. Great difficulties were also experienced in the development of the caterpillar type in bringing the design from the small 1-ton wagon size up to the much larger dimensions and weight needed to carry armour, guns, &c., so as to make the landships effective. As both the types thus presented difficulties, we decided that more experiments were necessary before proceeding further.

I should mention that during the early part of 1915 the War Office had, independently of the Admiralty, been investigating the proposition, and had made trials with Holt tractors. The results of these trials, however, showed that there was not much likelihood of a successful issue.

When Mr. Churchill left the Admiralty and Mr. Balfour became First Lord, I told him that I still had great confidence in our ability to produce a satisfactory landship, and he authorised me to continue the work. About this time, as the War Office had been investigating the matter, a joint committee was formed under General Scott-Moncrieff, who had been head of the War Office Committee, and we discussed the whole position, and he agreed that the lines of investigation pursued by the Admiralty Committee gave good promise.

At this period a specification of requirements of the military authorities and the conditions to be fulfilled by the landship were definitely enunciated by the War Office. The machine had to be capable of crossing gaps at least 5 ft. wide; fuel and water had to be carried for at least 20 miles; and parapets 5 ft. thick and 5 ft. high, having an exterior slope of 1 in 1 had to be negotiated. A reasonable limit of weight was imposed because of bridges which had to be crossed—not greater than that produced by 14 tons on an axle with a pair of wheels. The crew were to consist of about ten men, with two or more machine guns and a light Q.F. gun. The conditions were, however, subject to modification.

The laying down of the above requirements gave us something definite to work upon, and although we had been working for some time and had not reached any finality in design, our designs and experiments had been of great value. The conception of what was really necessary was taking shape in our minds as designers

FIG. 1. "LITTLE WILLIE."

FIG. 2. MARK I TANK.

Fig. 3.

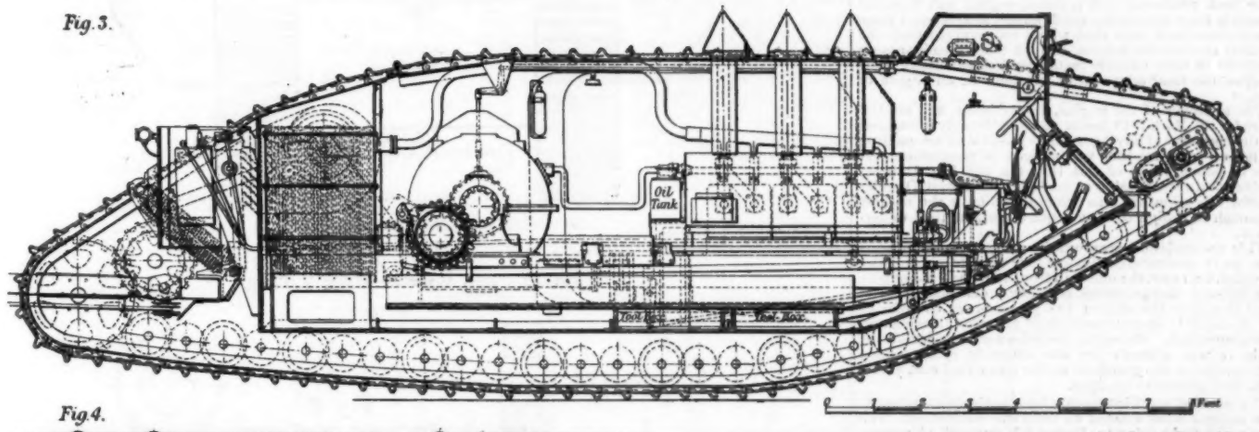
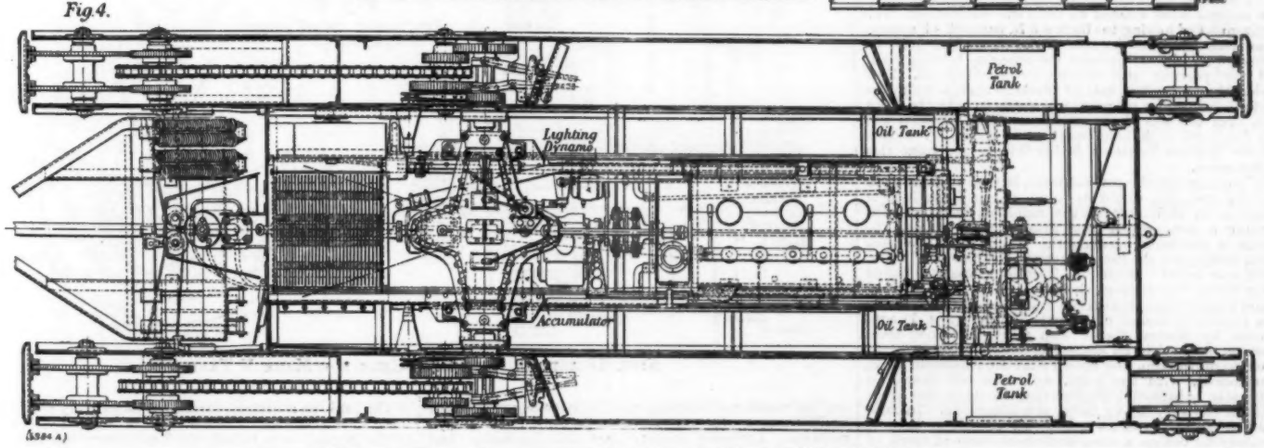


Fig. 4.



FIGS. 3 AND 4. LONGITUDINAL SECTION AND PLAN OF MARK I TANK.

and the possibilities of the situation were becoming clearer; and thus knowledge of the actual conditions to be fulfilled helped to crystallise our ideas.

The definite engineering problem before us was an entirely new one, and was by no means simple. The conditions laid down involved the following:—A machine able to move up a slope of 1 in 1. The dimensions were limited by the capacity of our railway trucks for weight carrying and by the loading gauges for passing over the railways of England and France. The machine had to carry a heavy weight of armour, armament, fuel, &c., whilst giving protection to its crew. It had to be very strong to bear the strains to which it would be subjected. It must be easily and quickly constructed, using reliable engines and other parts which could be readily produced in bulk after standardisation, and it had to be easily steered and controlled. It must have moderate pressure per square inch on the ground, and it must be habitable and well ventilated while being at the same time bullet-proof.

All these conditions were of an entirely novel character, and many of them incompatible with others: to combine them in one machine which had to be a low and inconspicuous object, was a problem indeed. Luckily we found men with engineering experience and great enthusiasm who were able to overcome all the difficulties. The debt we owe, especially to Sir William Tritton of Messrs. Foster's, and to Major Wilson for all they did, and to many others who contributed to the success of the tanks, is certainly a very great one.

Regarding the general question of obtaining suitable engines for driving the tanks, there is no doubt that, just as we owe the perfecting of the aeroplane, the airship and the submarine to the advantages of the internal combustion engine over that of any other known engine, we are equally indebted to that form of prime mover for the success of the tanks. It is possible that a design might have been produced with a steam engine, but it would certainly have involved a much larger, heavier and more conspicuous tank than that which was evolved with the internal combustion engine, and all these disadvantages would have been adverse factors and might easily have stopped the final adoption of the tank as an engine of war.

The selection of the engine, transmission and control gears for the Mark I–IV tanks was considerably influenced by the necessity of having as far as possible to use existing units and material that was already in production. It was in consequence of this that the 105 h.p. Daimler engines and transmission as made for the Foster-Daimler tractor was adopted; this combination gave the nearest approach in design to tank requirements as then understood.

This transmission gear was in many respects unsuitable, as it necessitated having four men to control the machine, i.e.: one, the officer in front to control the engine and forward change speed gear-box; one brakeman in front alongside the officer; two gearsmen at the rear of the machine to operate secondary gears for steering and changing speed. Owing to the noise and heat inside the tank, it was difficult for the officer to communicate instructions to the gearsmen at the rear; this was, therefore, done generally by signs.

The wheeled machine having been entirely abandoned, new designs were started to fulfil the conditions. The requirement of having to climb a 5 ft. parapet, of course, meant that the front portion of the caterpillar must be at least 5 ft. high to prevent the machine butting right into the parapet and coming to a standstill. This carried the caterpillar belt of track to such a height at the fore end, that a proposal was made to take the track right over the top of the machine. This problem was first discussed with Lieutenant, now Major, W. Wilson and Sir William Tritton; Major Wilson proposed this arrangement.

In working out the general form, it then became clear that the best plan would be to adopt the Naval idea of sponsons on each side of the machine, each sponson carrying a gun, which was thus situated about the middle of the tank between the tracks. It was this which really gave the first contour to the Number 1 tank, which was called "Mother." This tank was also called "Big Willie" to distinguish it from "Little Willie." I should mention here that trials made at Lincoln with the tank familiarly known as "Little Willie" (Fig. 1) constructed by Messrs. Foster with tracks obtained from America, and with an armoured body having a turret mounted on the top, had shown that the American track arrangement, with the links, &c., was not nearly of sufficiently substantial construction to stand the great strain of the very heavy body, armament, &c. In fact, "Little Willie" was no good. It, therefore, became necessary to design a completely new form of track of the very best material and workmanship, and this form of track was developed and used for the first completed machine.

The Landship Committee, which was still under the Admiralty at this time, concentrated all their efforts upon the development of one complete heavy tank to fulfil the conditions laid down, using all the experience they had gained with the various experiments previously made.

The question of armament was very fully gone into, and it was decided for the first tank to adopt a main armament of two 6 pdr. guns mounted each in a sponson on each side of the machine; there were five machine guns in addition. The 6 pdrs. were of Naval type, but the mounting had to be very carefully modified, and special sighting arrangements provided in order to adapt it to use in the tank; extreme care had to be taken to make the shield a good fit and the sighting slots as small as possible, in order to avoid the entry of any bullets into the tank.

The earlier tanks carried two long Naval guns, but in the later ones the 6 pdr. guns were shortened. The "Mother" tank was a complete machine, supplied with every arrangement then thought necessary. It was, however, only made of mild steel and was not therefore suitable for fighting. This tank was the prototype of all the British heavy tanks; and, although the later ones were enormously improved, the general form and the principles of construction were adhered to in all the subsequent British tanks of the heavy type.

After the first approval of the "Mother" tank, it was decided to construct two types—a male and female, these terms simply being given to distinguish one from the other. The male tanks were still armed with the two 6 pdrs. and a few machine guns, but the females were to carry an armament of machine guns only. Of course, much smaller sponsons were sufficient to accommodate machine guns than those required for the 6 pdrs. Generally speaking, the male tank sponsons had to be taken off for transport. This was done by removing certain bolts, and the sponsons, guns, &c., were carried independently, which, of course, had the effect of lightening the tanks and keeping their dimensions within the limits necessary for transport over the British and French railways. I should observe that this limitation had always to be kept in mind and prevented the development of any very large-size tanks. It also kept the size convenient for shipment and the weight within the limits of the capacity of bridges at the front.

In actual fighting, preference was generally given to the male over the female tanks by the majority of officers in command—the 6 pdrs. having a much more terrifying effect on the enemy, and being able to knock out machine-gun emplacements, often even destroying enemy field-gun batteries before the latter could hit the on-coming tank.

The "Mother" tank was shown to Lord Kitchener, the members of the Army Council, the Board of Admiralty and the Cabinet at Hatfield Park, which had been lent by Lord Salisbury to the Landship Committee on February 2, 1916. The trials here demonstrated that the tank could easily fulfil the conditions laid down, and were, in fact, such a success that it was decided to order a number of similar tanks to be produced. About a week later the working of the tank was demonstrated before His Majesty the King, who expressed his great interest and his wish for its success.

Immediately after the successful trials at Hatfield, Mr. Lloyd George (who was then Minister of Munitions) arranged, in consultation with Mr. Balfour, for the construction of a Tank Supply Committee under the Minister of Munitions, for the production of tanks in numbers. The President of this Committee was Lieutenant, now Sir A. A. G. Stern, who had been Secretary to the Admiralty Landship Committee under myself, and had always been a most enthusiastic advocate of tanks. I was still to remain Chief Technical Adviser on the Tank Supply Committee; the remaining three members of the Committee were: Major Swinton, Major Wheeler and Captain Tulloch, who had throughout most strongly urged the development of tanks, and had worked with Colonel Swinton on the subject.

The first tank to be made, which was practically a replica of the "Mother" tank shown at Hatfield, was called the "Mark I." The Mark I machines were provided, in the same manner as the "Mother" tank, with two heavy wheels at the rear, which were added firstly, for helping to steer a course, altering the line of advance of the tank to a limited extent. The primary object of these wheels, however—which could be lowered or raised off the ground—was to help the Tank over rough ground and reduce the shock when the tank, so to speak, "took a fence." The wheels could either be raised by hydraulic gear, thus acting as a weight at the back and moving the centre of gravity of the tank aft, or they could be pressed down on the ground, thus acting as a lifting force aft and virtually moving the centre of gravity of the tank forward. This arrangement, no doubt, increased the gap which the tank could negotiate and absorbed a good deal of the shock in plunging over rough ground; but these wheels were in practice found to be a nuisance and they were continually getting out of order and the connections being broken; in all the later tanks they were abandoned.

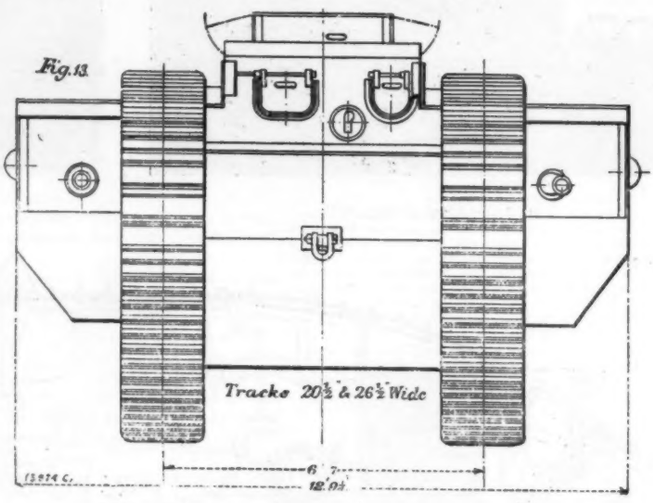
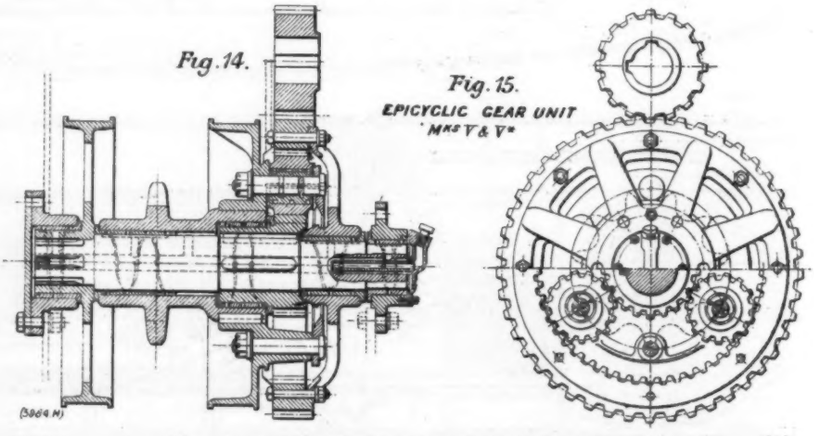


FIG. 13. END VIEW OF MARK V TANK.



FIGS. 14 AND 15. EPICYCLIC GEAR FOR MARK V TANK.

MARK I. TANK.

The general arrangement of Mark I tank, with the engine and transmission, tracks, &c., is illustrated by Figs. 3 and 4, page 335, while a photographic view is reproduced on Fig. 2. The main particulars and dimensions are given in the Table on page 337. The engine and much of the transmission gear of the Mark I machine is the same as had been previously

TABLE OF MAIN DIMENSIONS AND PARTICULARS OF TANKS.

Type of Machine.	Dates of Design, &c.					Weight.			Pressure per square inch in lbs.					Length and Width of Track in Ground Contact.			
	Date of Commencement of Design.	Builder of First Machine.	Principal Manufacturer.	Date of First Standard Machine.	Number of Machines produced up to December 31, 1918.	Total Weight in Fighting Trim in Tons.	Weight per horse-power in pounds.	Horse-power per Ton.	Number Sinkage.	2-inch, Sinkage.	4-inch, Sinkage.	6-inch, Sinkage.	Sunk to Belly.	Width of Track Plates.	Length of Track on each Side in Ground Contact. No Sinkage.	Length of Track on each Side in Ground Contact, when Sunk to Belly and Machine at Rest.	Length of Track on Each Side in Ground Contact when sunk to Belly and Machine in Motion.
						lbs.	h.p.							in.	ft. in.	ft. in.	ft. in.
Mark I ..	Oct., 1915	Foster and Co., Ltd., Lincoln	Metropolitan Carriage and Wagon Co.	Dec., 1915	Male, 75 .. Female, 75	Male, 28 .. Female, 27	597	3·75	27·8	24·6	16·9	13·0	11·6	20½	4 7	17 0	11 0
Mark II ..	Feb., 1916	,,	,,	Jan., 1917	Male, 25 .. Female, 25	Male, 28 .. Female, 27	597	3·75	27·8	24·6	16·9	13·0	11·6	20½	4 7	17 0	11 0
Mark III ..	Feb., 1916	Metropolitan Carriage and Wagon Co.	,,	Jan., 1917	Male, 25 .. Female, 25	Male, 28 .. Female, 27	597	3·75	27·8	24·6	16·9	13·0	11·6	20½	4 7	17 0	11 0
Mark IV ..	Oct., 1916	Foster and Co., Ltd., Lincoln	,,	Mar., 1917	Male, 420 .. Female, 595	Male, 28 .. Female, 27	597	3·75	27·8	24·6	16·9	13·0	11·6	20½	4 7	17 0	11 0
Mark V ..	Oct., 1917	Metropolitan Carriage and Wagon Co., Ltd.	,,	Jan., 1918	Male, 200 .. Female, 200	Male, 29 .. Female, 28	430	5·2	28·7	25·0	20½ inch tracks. 17·0	13·0	12·0	20½ and 26½	4 7	17 0	11 0
Mark V* ..	Feb., 1918	,,	,,	May, 1918	Male, 200 .. Female, 432	Male, 33 .. Female, 32	499	4·28	22·2	19·4	26½-inch tracks. 13·2	11·0	9·3				
									14·2	—	20½-inch tracks. —	12·0	8·9	20½ and 26½	10 7	22 0	17 0
Mark V** ..	May, 1918	,,	,,	Dec., 1918	1 made ..	Male, 35 .. Female, 34	348	6·4	11·0	—	26½-inch tracks. —	9·3	6·6				
									26·5	—	21·2	13·2	9·0	20½ and 26½	6 0	23 6	17 6
Mark VII ..	Dec., 1917	Brown Bros., Edinburgh	Brown Bros., Edinburgh	July, 1918	3 made ..	33	493	—	25·0	23·0	15·9	12·3	10·8	26½	4 7	18 0	12 6
Mark VIII ..	Dec., 1917	North British Loco. Co., Ltd., Glasgow	North British Loco. Co., Ltd., Glasgow	Oct., 1918	7 made ..	37	270	8·0	18·0	—	—	13·3	6·3	26½	7 6	—	21 0
Mark IX ..	Sept., 1917	Armstrong, Whitworth	Marshalls, Gainsboro'	June, 1918	35 made ..	27, unloaded 37, loaded	550	4·05	28·0	—	19·0	13·7	6·9	20½	6 0	—	24 0
Gun-carrying tank	July, 1916	Metropolitan Carriage and Wagon Co., Ltd.	Kitson & Co., Leeds	Jan., 1917	48 made ..	27, unloaded 34, loaded, With gun and ammn.	576	3·9	29·8	20·0	11·5	10·7	7·0	20½	11 7	—	19 0
Medium Mark A whippet	Dec., 1916	Foster and Co., Ltd., Lincoln	Foster and Co., Ltd., Lincoln	Oct., 1917	200 made ..	14	348	6·43	15·8	—	13·6	9·8	4·5	20½	4 0	17 0	14 0
Medium B ..	June, 1917	Metropolitan Carriage and Wagon Co., Ltd.	North British Loco. Co., Ltd., Glasgow	Sept., 1918	45 made ..	18	403	5·5	14·8	14·0	12·4	9·3	5·3	22½	5 0	—	14 0

Total number of tanks constructed, 2,636.

TABLE—(*continued*).

Type of Machine.	Main Dimensions.				Armour Plate Thickness in Millimetres.			At Normal Engine Revolutions. Speed in Miles per Hour.					Fuel.				Armament and Ammunition.			Tractive Force.	
	Length Overall.	Width Overall.	Height from Ground to Underside of Belly.	Height to Top of Tracks.	Maximum Thickness in Millimetres.	Minimum Thickness in Millimetres.	Thickness of Track Plates in Millimetres.	First Gear.	Second Gear.	Third Gear.	Fourth Gear.	Reverse.	Petrol Capacity in Gallons.	Estimated Mileage, without Refilling.	Maximum Width of Trench that can be Crossed without Falling in.	Crew.	Engine.	Number of 6-pdr. Guns Carried.	Number of Machine Guns Carried.	Ammunition Carried.	Theoretical Tractive Force of Machine in First Speed, in Tons.	Theoretical Tractive Force of Machine per Ton. Weight of Machine in Tons.
	ft. in.	ft. in.	ft. in.	ft. in.	mm.	mm.	mm.								ft. in.							
Mark I ..	32 6 with tail, 26 5 without tail	13 9	1 4½	7 4½	12	6	10	0·75	1·3	2·1	3·7	0·94	46	23	10 0	8	6-cyl. Daimler, 105 h.p., 1,000 normal r.p.m.	0, female 2, male	5, female 4, male	31,232 S.A.A., female 324 6-pdr., male 6,272 S.A.A., male	23·7	0·85
Mark II ..	32 6 with tail, 26 5 without tail	13 9	1 4½	7 4½	12	6	10	0·75	1·3	2·1	3·7	0·94	46	23	10 0	8	,,	0, female 2, male	5, female 4, male	,,	23·7	0·85
Mark III ..	32 6 with tail, 26 5 without tail	13 9	1 4½	7 4½	12	6	10	0·75	1·3	2·1	3·7	0·94	46	23	10 0	8	,,	0, female 2, male	5, female 4, male	,,	23·7	0·85
Mark IV ..	26 5	13 6	1 4½	7 4½	12	6	10	0·75	1·3	2·1	3·7	0·94	70	35	10 0	8	,,	0, female 2, male	6, female 4, male	12,972 S.A.A., female 204 6-pdr., male 5,640 S.A.A., male	23·7	0·85
Mark V ..	26 5	13 6	1 4½	7 4½	14	6	10	0·9	1·5	2·6	4·6	0·9	93	45	10 0	8	6-cyl. Ricardo, 150 h.p., at 1,200 r.p.m.	0, female 2, male	6, female 4, male	16,200 S.A.A., female 207 6-pdr., male 7,800 S.A.A., male	27·3	0·94
Mark V* ..	32 5	13 6	1 4½	7 4½	14	6	10	0·9	1·5	2·6	4·6	0·9	93	40	13 0	8	,,	0, female 2, male	6, female 4, male	,,	27·3	
Mark V** ..	32 5	13 6	1 4½	7 4½	14	6	10	1·04	1·7	3·02	5·2	1·04	200	67	13 0	8	6-cyl. Ricardo, 225 h.p., at 1,200 r.p.m.	0, female 2, male	6, female 4, male	,,	36·1	1·03
Mark VII ..	29 10	13 9	1 4½	7 4½	12	6	10	0	Variable to			4·25	100	50	10 0	8	6-cyl. Ricardo, 150 h.p., at 1,200 r.p.m.	0, female 2, male	6, female 4, male	,,	32·3	1·1
Mark VIII ..	34 2½	12 4	1 9	7 6½	16	6	8	1·4	—	—	5·2	1·4	200	55	14 0	8	12-cyl. Ricardo, 300 h.p., at 1,400 r.p.m.	0, female 2, male	7	208 6-pdr., 13,200 S.A.A.	42	1·14
Mark IX ..	31 11	8 1	1 9½	7 8	10	6	10	0·86	1·4	2·5	4·3	0·86	100	42	12 6	4 can carry 50 men 4 and gun detachment	6-cyl. Ricardo, 150 h.p., at 1,200 r.p.m.	None	2	900 S.A.A.	29·2	0·79
Gun-carrying tank	43 0 with tail, 30 0 without tail	11 0	1 3½	—	8	8	10	0·75	1·3	2·1	3·7	0·94	80	35	11 6		6-cyl. Daimler, 105 h.p., at 1,000 r.p.m.	None	None	None	23·7	0·70
Medium Mark A whippet	20 0	8 7	1 10	4 6	14	5	6	1·5	3·25	5·5	8·3	—	70	80	7 0	3	2-45 h.p. Tylor engines, total 90 h.p., at 1,000 r.p.m.	None	4	5,400	12·4	0·88
Medium B ..	22 9½	9 3	1 5½	5 9½	14	6	6	1·2	2·3	3·8	6·1	—	85	65	8 0	4	4-cyl. Ricardo, 100 h.p., at 1,200 r.p.m.	None	4	7,500	14·0	0·78

used in the Foster-Daimler tractors, and consists of the following units :—

Engine.—Six-cylinder sleeve valve Daimler engine giving 105 h.p. at 1,000 revs. No silencer was provided—the exhaust pipes going straight through the roof.

Clutch.—The clutch was of the cone type, being faced with ferodo and operated by a pedal from the driver's seat and connected to the gear-box by leather couplings.

Gear-box and Connections.—Sliding gears giving two speeds forward and reverse—the gear-box being operated by a hand lever from the driver's seat. The gear-box transmitted the power to a large worm and worm wheel, which enclosed the differential gear provided for use when steering with the tail or by hand brakes. The power is taken from the worm wheel by cross shafts, on which were mounted two sliding gears, these secondary gears meshing alternatively with two spur wheels mounted on each side of the chain pinion and were operated by striking forks which controlled both the change speed and the steering as described later.

Chain Drive was taken by a special 3-in. Coventry chain to the driven chain wheel at the rear of the machine on which were mounted the track pinions which engage with the track driving wheels, which again engage with the track links passing all round the machine.

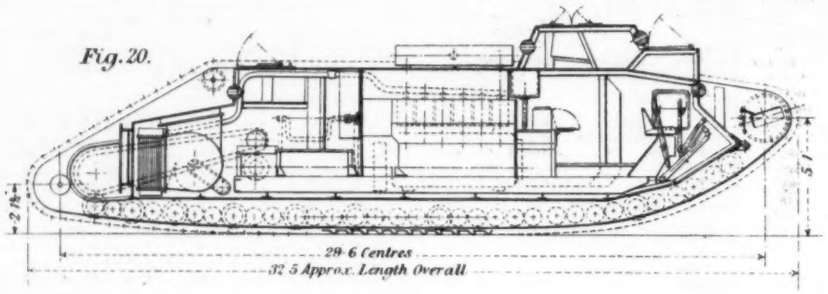
A track adjusting wheel was provided and carried the track around the front of the machine ; 26 track rollers were mounted under the machine rolling direct on to the track links.

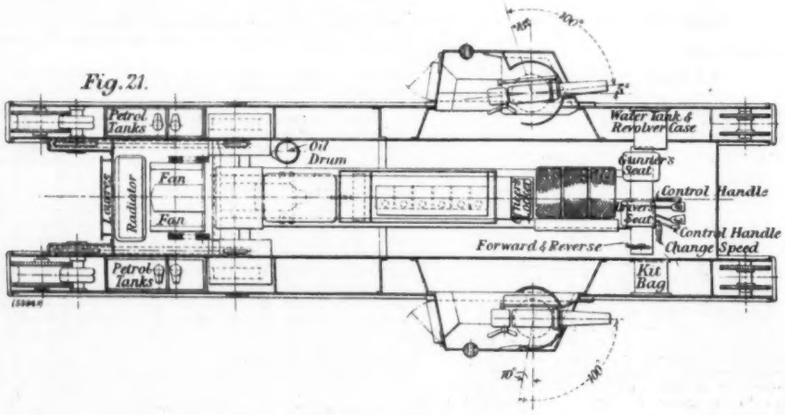
Steering System.—For sharp turns, after raising the tail the tank is steered by locking the differential, putting the secondary gear on one side into neutral and holding the track with its hand-brake, the other track running as usual. Gradual turns are made by unlocking the differential and moving the handwheel which actuates wire ropes by means of which the steering wheels are moved through an angle, thus causing the tank to turn. The steering tail consists of two wheels 4 ft. 6 in. diameter mounted at one end of a frame, which is pivoted near the other end, at this end are attached eight springs in tension, by means of which the wheels are kept in contact with the ground ; to this end is also attached a hydraulic ram actuated by a pump, with friction drive off the vibration damper, which raises the tail off the ground when put in action. In the later machines shields were fitted over the hydraulic lifting gear.

The Mark I tank was put in hand in the early part of 1916 and a number of these tanks were finished in August and September of that year. These were the tanks which were first used in action at the Battle of the Somme on September 15, 1916. On this occasion some 50 tanks were available for action, and considering that it was the first time that they were ever used on the field of battle and that the nature of the ground was very difficult, they did exceedingly well, although a considerable number of them broke down or got stuck in the mud. This first début of the tanks created great sensation and there is no question they were most effective in overcoming some of the enemy strong points which could have held out against our infantry without the assistance of the tanks ; but the conditions were such that the tanks really hardly proved their full value in this battle, and the date is chiefly remarkable for starting a new form of warfare with an entirely new type of war-engine which was likely in the future completely to alter tactics.

It proved that the machine was, in principle, sound, but that mechanical improvements were required, and as with every mechanical appliance limitations as to the possibilities of its use had to be recognised, and suitable conditions chosen in order to give the machine a chance of making good.

Up to the date of the Battle of the Somme the whole undertaking had been kept profoundly secret, and I may say that special pains were taken to achieve this result. I think it was a rather remarkable success, considering how difficult it is to keep secret an important undertaking of this kind, involving the manufacture of a large number of machines in different parts of the kingdom, a knowledge of which was necessarily gained by a great many people. However, our efforts in this direction were so successful that the appearance of the tanks in the Battle of the Somme was a surprise even to many of our own military officers who were on that part of the front. The enemy were certainly quite taken by surprise ; luckily they do not appear to have attached the importance to this new development which it really warranted. This was no doubt due to the fact that the tanks did not do as much as they might have done, had the crews had more training and had they been used under more favourable conditions. However, very important lessons were learnt by their use at the Battle of the Somme which enabled us to profit by the experience for the future.





FIGS. 20 TO 22. MARK V** TANK.

MARKS II AND III TANKS.

Marks II and III are practically the same as Mark I, with certain minor differences and improvements. During the production of Marks I, II and III, the methods of improving the design generally were continually under consideration, the chief aim being to obtain a more powerful prime mover than the 105 h.p. Daimler engine which had been fitted to all tanks, and so to increase the speed and also to improve the control.

MARK IV TANK.

The Mark IV machine, which is illustrated by the general arrangement drawings, Figs. 5 to 7, and by the perspective view (Fig. 8) and a view of a damaged tank (Fig. 9) on Plate XVI, was the same as the Mark I with the exception of the following improvements :—

(1) The steering tail was found to be too weak in construction, and owing to its operation and use not being understood by the average driver, it was unsatisfactory, and was, therefore, discontinued.

(2) Improved design and material for track rollers (see Fig. 7).

(3) Improved method of stowing sponsons for the conveyance of the tank by rail.

(4) Lewis guns were adopted instead of Vickers. This involved alterations in the mounting.

(5) The later Mark IV machines were fitted with "tubular" instead of "envelope" radiators.

(6) A silencer was fitted.

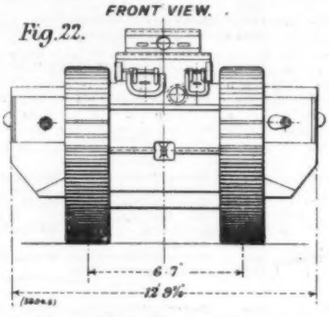
(7) The driver's turret was reduced in width to allow the use of wider track shoes if required.

(8) Owing to the danger of fire the petrol tanks were removed from the inside of the machine and placed outside at the rear.

(9) Short 6-pdr. guns were adopted.

Steering System.—For sharp turns the tank is steered by putting the secondary gears on one side into neutral "position," and holding the track with the hand brake, the other track running as usual. Small deviations from the straight, as, for instance, when running along a road, can be corrected by unlocking the differential and checking one track by means of the hand brake.

Mark IV, male and female, became the standard tanks for use at the front in 1917, and this was the type of tank which, with the help of a few of the earlier ones, went into action at the Battle of Cambrai, November 20, when, without artillery preparation, the tanks advanced over the Hindenburg Line and were chiefly instrumental in gaining a victory. This was by far the most important tank battle hitherto fought, for it proved that with good training and with a proper combination with the infantry, the enemy lines could be broken without artillery preparation, which had hitherto been found absolutely necessary. Commanded in person by General H. Elles, the tanks advanced over the trenches, some of which were of a most formidable character, special arrangements having been made for the tanks to negotiate the widest of these trenches.



They broke down all the wire so that infantry or cavalry could follow. In fact, the Battle of Cambrai opened an entirely new phase of warfare, which was due to the work the tanks were able to accomplish.

The results of the victory of November 20 were discounted ten days later by the German regaining a great deal of the ground they had lost on the former date ; but, in spite of this reverse on November 30, the importance of the work the tanks had done was not depreciated.

During 1917 the Germans had already begun to take measures against attacks by tanks, but after the Battle of Cambrai the steps they took were of a much more important character, showing the respect which they at last had for this new weapon of warfare.

During this year (1917) the further development and improvement of British tanks had been very carefully considered. Mark IV, though an improvement on the earlier ones, still left a good deal to be desired—especially in the way of speed and control. Up to this date the most powerful suitable engine which we had been able to use for the tanks had been the 105 h.p. Daimler, the power of which had been somewhat increased by the use of aluminium pistons ; but there was no doubt that a greater power still was necessary to increase the speed of the tanks. The engine specially designed by Mr. Ricardo had in the meantime been developed and tried, and during 1917 this was brought into the bulk-production scheme, and a number of these engines of 150 h.p. were put in hand for the tanks of 1918.

The question of control and transmission had also been very carefully considered, and Major Wilson had adapted a special epicyclic arrangement for use with the tanks. This arrangement took a good deal of working out, but in the end proved most successful and was adopted, together with the Ricardo engine, for the Mark V tank. The Mark V was in form and size and in general principles, a development of the Mark IV, but the increased power and the epicyclic gear, which gave one-man control and improved steering, were two most important improvements, and there is no question that Mark V tank, used in 1918, was by far the most effective of all the heavy tanks produced. The speed was increased from 3·7 m.p.h. in Mark IV to 4·7 m.p.h. in Mark V, and with the one-man control the average speed of Mark V was even higher than these figures would indicate, as with the Mark IV, owing to the difficulty of changing gear, the tendency was to leave the low gear in all the time.

MARK V TANK.

A perspective view of Mark V tank is given in Fig. 10 and longitudinal section and plan in Figs. 11 and 12 on Plate XVII and an end view in Fig. 13 on page 336. The epicyclic gear is shown in Figs. 14 and 15, page 336. The dimensions, &c., are given in the table. The armour thicknesses were increased in Mark V, as shown in the table, above those previously adopted. All this armour was very specially tested and for all the earlier tanks was made by Messrs. Beardmore, who did most useful work in experimenting and developing this thin armour for tanks.

The general outline of the hull and tracks of Mark V

was the same as in previous machines. The following important improvements, however, were introduced :—

(1) Increase of engine power and the employment of an engine specially designed to meet service conditions.

(2) Improved manœuvring powers and one man control by means of epicyclic gear.

(3) Improved observation.

(4) Means of fixing unditching gear from the inside of the machine.

(5) Improved mud chutes for cleaning the track.

The Engine used was the 6-cylinder 150 h.p. Ricardo engine which was specially designed for this tank—the power was taken by means of a plate clutch operated by a pedal from the driver's seat. A four-speed gearbox of the motor car type, operates by means of reversing bevels, the cross shaft on the ends of which were mounted spur pinions driving the planetary rings of the epicyclic gear, the sun wheels of which being held by a reaction brake causes the planet discs to rotate and drive the chain sprockets and track brake drums. The remainder of the transmission of the track was similar to that in the previous types of machines.

Steering.—By releasing one or other epicyclic brakes the power is cut off from the corresponding track and transferred to the other track. This normally is sufficient to change the direction of the machine, but for very sharp turns the track brake pedal is depressed, and this automatically operates the brake on the track from which the power has been cut off.

MARK V* TANK.

There were two modifications of Mark V tank, one was Mark V* which had 6 ft. added in the middle of its length, giving room for more infantry being carried besides the crew of the tank, and also enabling the tank to cross a somewhat larger gap. This Mark V* is illustrated by Figs. 16 to 19, on Plate XVIII. In addition, there was a Mark V**, which was the same as the Mark V*, but had a still more powerful Ricardo engine of 225 h.p. Mark V** is illustrated by Figs. 20 to 22 on page 338.

MARK VI TANK.

During the gradual development of the tanks the question of transmission had always exercised our minds, and a great number of experiments were made and various transmissions experimented with. The petrol-electric type, which was rather favoured by some of the French designers, was investigated ; but it was found that there would be a good deal of trouble in developing this and bringing it to the stage of production in numbers. Another form of transmission was investigated, viz., the Williams-Janney variable speed gear. I need not give a description of this gear, which is pretty well known,* and which is used a good deal for various purposes in our warships. A tank was built with this gear and showed remarkable qualities. It was exceedingly easy to drive, and owing to the nature of the gear, practically full power could be developed at all speeds from the lowest to the highest. This was so successful that a number of tanks, which were termed Mark VII, were ordered with this gear, the tanks otherwise being the same as Mark IV. It was impossible, however, to produce them in really large numbers, as there would have been great difficulty in making arrangements for the bulk manufacture of the Williams-Janney gear and the necessity for the gear really disappeared with the introduction and perfecting of the epicyclic gear, as arranged by Major Wilson. The Mark VI never got beyond the design stage. It was of a different type and was to have only one 6-pdr. in front instead of two in sponsons. It is not, therefore, necessary to say anything further about this type.

MARK VII TANK.

The general arrangement of this Mark VII tank is shown on Plate XIX. The chief feature of this machine, as already stated, was the use of the Janney Williams variable speed gear units. The general arrangement of this transmission is shown in the drawings reproduced. The power from the engine which was 150 h.p. Ricardo was taken through reduction spur gears to two hydraulic variable speed gear units and thence by bevels to two independent cross-shafts to helical reduction gears which transmitted the power, by means of chains, direct to the track sprockets. Each of the variable speed units was controlled by means of separate hand wheels—from these hand wheels the track could then be controlled individually for steering or both together for changing speed. To appreciate the great advantage of this form of change speed gear it should be pointed out that in other forms of speed gear used in tanks, more especially the early types, the machine generally came to rest whilst a gear change was being made. A small oil radiator was used for cooling the oiling system. The hull of the Mark VII was similar to the Mark IV and Mark V machines with the exception that it was 3 ft. 6 in. longer. An electric self-starter for the engine was first used on this machine. Figs. 26 and 27, on Plate XIX, illustrate the lighter type of track rollers used in some of the tanks ; the drawings are self-explanatory.

(To be continued.)

MIDDLESBROUGH PIG-IRON SHIPMENTS.—Messrs. William Jacks and Co., 5, East India Avenue, E.C., state that the pig-iron shipments from Middlesbrough, including Skinningrove, in August, were 1,785 tons coastwise and 22,071 tons foreign (of which 10,793 tons went to Belgium), a total of 23,856 tons. The total for August of last year was 48,593 tons, and for August, 1917, 59,083 tons.

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* See ENGINEERING, vol. cvii, pages 663, 698 and 794.

"THE BUILDING OF AIRSHIPS."

TO THE EDITOR OF ENGINEERING.

SIR,—So far as they apply, "Winco's" remarks in his letter which appeared in your issue of the 29th ult. merely confirm my original contention that *nothing has yet been accomplished which gives the remotest indication of the possible commercial value of airships in the future.* "Winco" appears to be obsessed with the idea that my opportunity of obtaining reliable information on the subject is limited, though why he should make this assumption, I am unable to conjecture. Admitting that an air of mystery surrounds most service matters, there could never be any question of official secrecy attached to the various points raised in my previous letter, as these were based on well-known facts. The whole problem is purely one of common-sense and ordinary book-keeping, and is not to be solved by mere post-prandial expressions of opinion.

With regard to the danger from fire, whilst this risk is admittedly small, it is still a factor to be taken into consideration. In this matter "Winco's" statement of the actual losses in the air from this cause, during the war, arising from accident, is unfortunately incorrect—I refer to Great Britain and British waters alone—and suggests that his opportunities for obtaining information relating to airships are even more limited than he assumes mine to have been.

So far as concerns "mooring-out," I was unfortunately not able to be present at the Aero Club on the occasion to which "Winco" refers. That, however, does not alter the fact that never since the days of the "Nulli Secundus" or even earlier, when "mast mooring" was originally tried, has it been found possible to moor an airship in this way without "landing" it first. From this it would appear that "Winco" has been misinformed in so far that mast-mooring consequently does not effect any reduction in the normal strength of the landing party required.

The figures given by "Winco" for R. 34 entirely substantiate my statement that an airship of this type is useless for long-distance commercial flying. To illustrate this in detail, consider the case of a voyage of, say, 3,000 miles at an average speed of 40 m.p.h. This is equivalent to an air speed of 60 m.p.h. against an adverse head wind of 20 m.p.h., a by no means unfair assumption of average possible conditions.

Such a voyage would take 75 hours. According to "Winco" this would require a minimum of $75 \times 700 = 52{,}500$ lb. of petrol and oil to be taken on board before starting the trip, without allowing anything for contingencies, out of an originally available lift of $30 \times 2{,}240 = 67{,}200$ lb. (again I am quoting "Winco").

This leaves a balance of, say, 6¼ tons available for water ballast, crew, &c., so that at the very utmost not more than perhaps 2 tons actual cargo-carrying capacity are available. For a voyage of greater length this would be further reduced till the limit of distance of about 3,500 miles is reached, when there would be no surplus margin for cargo at all and the voyage would end for want of fuel.

"Winco" refers, somewhat nebulously, to difficulties in the commercial development of rigid airships, which he maintains can only be overcome by further experiment. Unfortunately, he does not give any indication as to the nature of these difficulties. He entirely overlooks the fact that the one insuperable objection to commercial long-distance flying by airship is not a matter of technical difficulty but the enormous cost of such a service, due primarily to the magnitude of the overhead charges, which no amount of experimenting can appreciably reduce. In comparison with these charges, the actual running cost is almost negligible, though both have obviously to be considered in comparing the economy of competitive methods of transport.

In conclusion, may I point out that since this correspondence was started the Government have abandoned their airship programme. From this it would appear that "Somebody-in-authority" has at last seen things in their true perspective and has had the courage (and power) of his convictions. Presumably some of the high-placed officials at the Air Ministry will now follow the "little brown girls with pigtails," or will be going back to sea. In the meantime, this action on the part of the Government affords the strongest possible confirmation of the correctness of my contention.

Yours faithfully,

CECIL LIGHTFOOT, A.M.I.C.E.

9H, Cornwall Mansions, Regent's Park,
September 8, 1919.

UNIVERSITY MATHEMATICS FOR ENGINEERS.

TO THE EDITOR OF ENGINEERING.

SIR,—It is fortunate for me that ENGINEERING is not the sort of journal one simply looks through and throws away. Most of your readers will be able to refer to my letter in your issue dated August 15, and they will then see that I am not guilty of any such oversight as is suggested by Mr. Hughes in your current issue. My remark that he quotes in his second paragraph certainly does appear to be wrong ; but this is because he omits to mention my perfectly clear statement that I was referring to the circle of unit radius and the hyperbola that corresponds to that circle. There was no call for me to consider any other hyperbola, this being the only one referred to in the piece of erroneous teaching that I was rectifying.

I will not make any critical remarks on the quotations that Mr. Hughes has made from Mr. Edser's book ; for it may be that he is quoting from this book with the same carelessness as from my letter, in which case my criticisms might be doing Mr. Edser an injustice. Besides, if this writer and other English teachers have been right on the matter of the hyperbolic functions, that does not in any way contradict what I have said. I did not lay claim to any originality in this particular instance, but said that I had found the correct teaching in a book by an American professor ; and I know there are many English teachers quite equal to me as regards the ability to copy from other people's books.

It may be well for me to remind your readers that my argument was this : (1) That the mathematical teaching of engineers at the University of London has been decidedly erroneous on the above and other matters, as can be proved from the book that has just been written by one of their lecturers in engineering mathematics (assisted by at least three other bachelors of science) ; and (2) that this University, like others with which I have communicated (at Oxford, Cambridge, Leeds, Manchester, Durham, Edinburgh, St. Andrews and Dublin), "seem determined to go on misleading their students with erroneous teaching, in preference to admitting that they have done so hitherto." If my point about the hyperbolic functions was understood in 1901 by Mr. Edser and others, this only makes it the more remarkable that the point should now be misunderstood by University lecturers.

I can assure Mr. Hughes, and others who may read my letter in the same way, that I think the best teachers of engineering mathematics in this country are at least equal to the best in America. But in America the best men stand a greater chance of getting important appointments ; and that is how the American students are placed at an advantage over ours.

Yours respectfully,

W. F. DUNTON.

165, Tamworth-road, Newcastle-on-Tyne,
September 8, 1919.

TO THE EDITOR OF ENGINEERING.

SIR,—Your correspondent of August 15 has the writer's agreement with his conclusion as to nineteen-twentieths of mathematical teaching in technical colleges, which is futile from its lack of vision and of purpose. But it is not agreed that his illustration helps much to widen the vision or to elevate the purpose.

Actually, the divided circle has an enormous range of applications of the most fundamental importance for measurements of precision in surveying, navigation, astronomy, crystallography, spectroscopy, &c.

From this purely geometrical definition of the variable as a portion of the circular arc, the circular functions are naturally derived (for a real variable only) and a course based on the elementary geometry of the circle is an entirely suitable introduction to the circular functions.

There are no such applications of the equi-areal division of the hyperbolic arc.

In analysis, freed from the limitations of geometrical interpretation, the integration of a fraction, whose denominator is the square root of a quadratic, defines the inverse exponential, circular, and hyperbolic functions, and thence the direct functions without restriction to real values of the variable.

Thus are obtained the relations :—

$$2\cosh(i\,X) = 2\cos(X) = \text{Exp.}(i\,X) + \text{Exp.}(-i\,X)$$
$$2\sinh(i\,X) = 2i\sin(X) = \text{Exp.}(i\,X) - \text{Exp.}(i\,X)$$

It is at once obvious that the substitution of an imaginary variable for a real variable transforms the hyperbolic function into the circular and *vice versa*.

In this notation the addition theorems, and the expansions in series for computation of tables, are identical in form, and differ in arithmetical detail only in the signs of terms.

The desire of your correspondent to generalise is in the true spirit of modern mathematics, but the solution is to be found in the application of function theory and not in restricted geometrical analogies, however ingenious.

The hall-mark of bad teaching is a wearisome crop of special proofs for analogous cases, in which kind geometrical conics is notoriously prolific.

Projective geometry, properly taught, can to a large extent remove this reproach, but even projective geometry suffers badly from the fatal attraction of the tricky special demonstration for the teacher who thinks in examination questions.

The study of the elementary theory of functions supplies a corrective.

"Think in Functions" is a recent cry of German mathematical reformers, which our teachers might well take up.

I am, &c.,

London, September 9, 1919. A.R.L.

LONDON SCHOOL OF ECONOMICS AND POLITICAL SCIENCE.—A series of lectures are announced to take place as follows :—"The Public Service in War and in Peace," by Sir William Beveridge, K.C.B., M.A., B.C.L., on Wednesday, October 1, at 5.30 p.m. "Railway Professional Education," by W. M. Acworth, M.A., on Thursday, October 2, at 6.15 p.m. "The Importance of the River Rhine in the New Map of Europe," by H. J. Mackinder, M.A., M.P., on Friday, October 3, at 5 p.m. "British Prize Courts and Prize Law during the Great War," by A. Pearce Higgins, C.B.E., M.A., LL.D., on Wednesday, October 8, at 5 p.m. "International Labour Legislation," a course of three lectures by Professor Sir John Macdonell, K.C.B., M.A., LL.D., F.B.A., on Thursdays, at 5.30 p.m., in Michaelmas Term, beginning November 20. For particulars of these and other lectures at the London School of Economics and Political Science, applications should be addressed to the School, Clare Market, Portugal Street, Kingsway, W.C.2.

GEARED TURBINE PROPELLING MACHINERY OF H.M.S. "RALEIGH."

CONSTRUCTED BY MESSRS. WILLIAM BEARDMORE AND CO., LIMITED, DALMUIR.

(*For Description, see opposite Page.*)

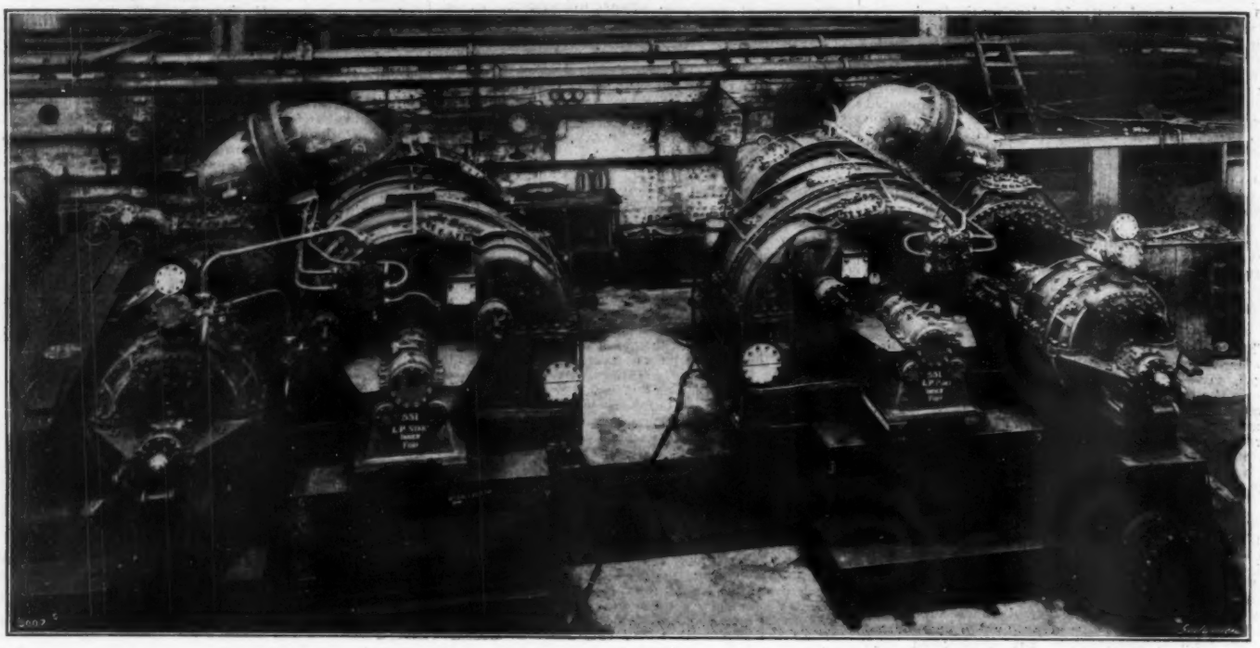


FIG. 1.

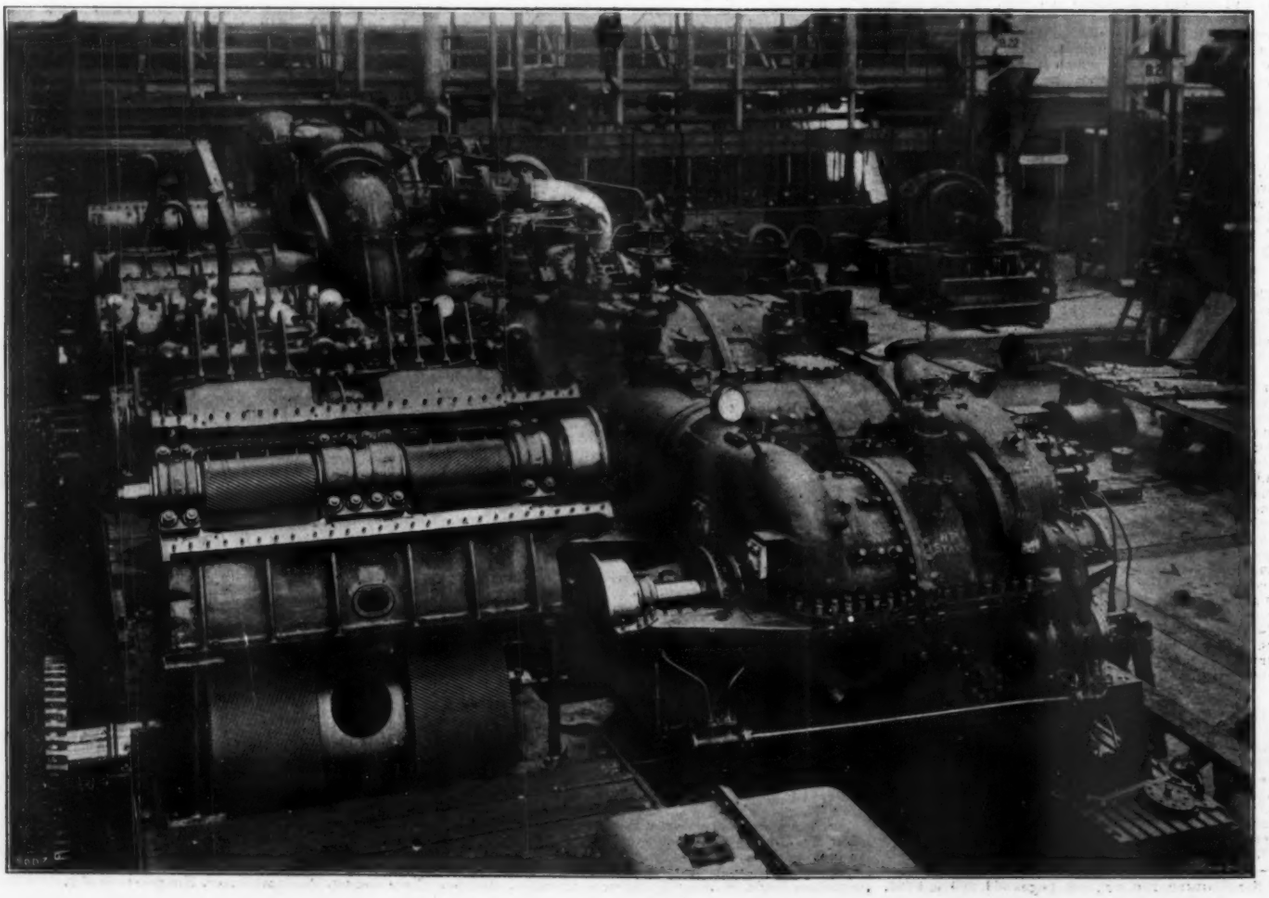


FIG. 2.

GEARED TURBINE PROPELLING MACHINERY OF H.M.S. "RALEIGH."

CONSTRUCTED BY MESSRS. WILLIAM BEARDMORE AND CO., LIMITED, DALMUIR.

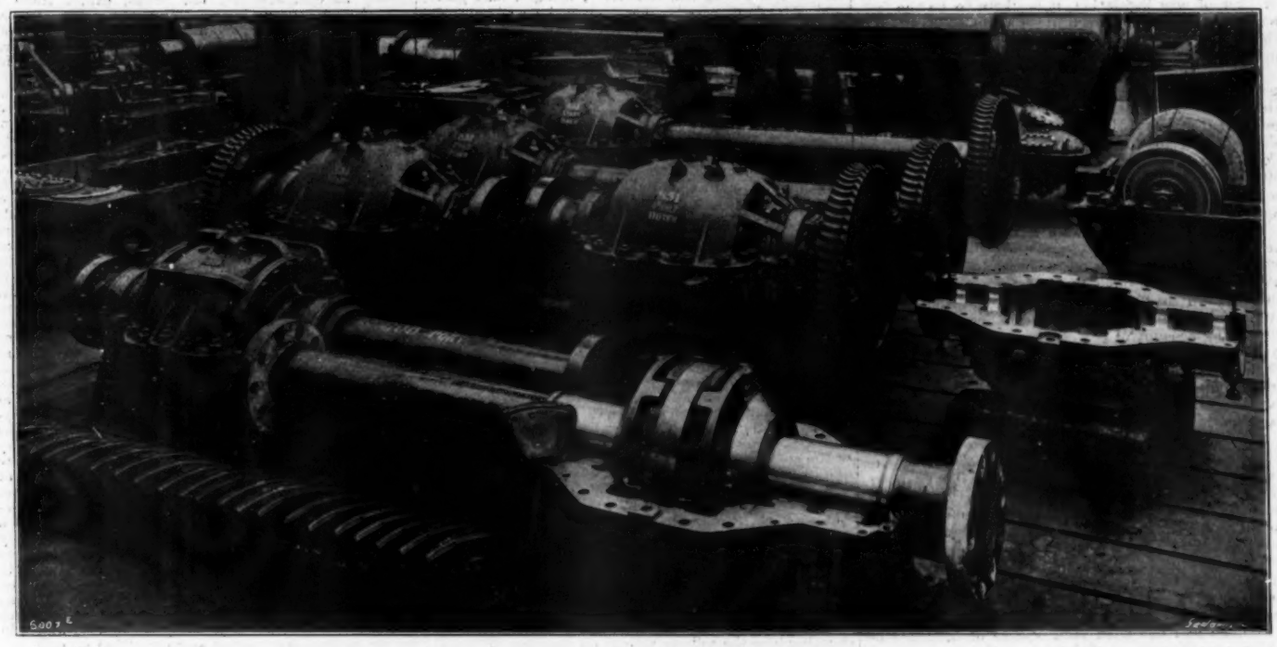


FIG. 3. MICHELL THRUST BEARING.

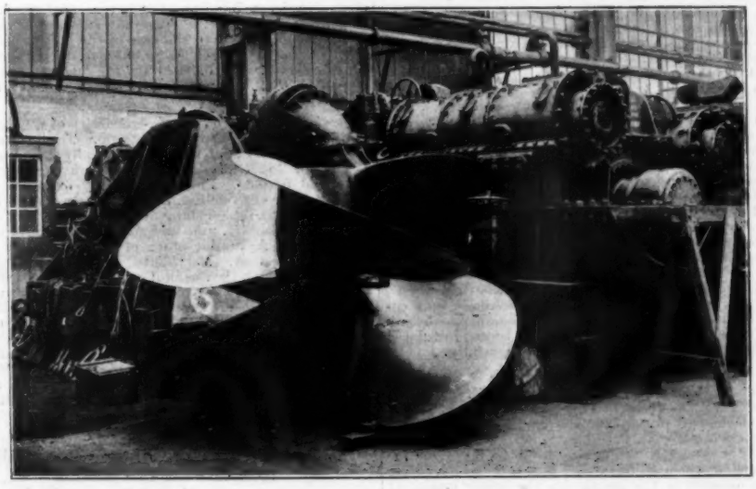


FIG. 4. PROPELLERS.

ON the 28th ultimo there was launched from the Naval Construction Works of Messrs. William Beardmore and Co., Limited, at Dalmuir, the name ship of a new class of protected light cruisers, for which designs were prepared in the summer of 1915. These vessels, of which some particulars were given in Sir Eustace H. T. d'Eyncourt's paper at the Spring Meeting of the Institution of Naval Architects (published on page 487 of our last volume), are considerably heavier than the earlier classes of light cruisers, and are intended for ocean work in any part of the world. They are 565 ft. in length, with a beam of 65 ft., a draught of 17·3 ft., and a displacement of 9,750 tons. The machinery was originally designed to develop 60,000 shaft horse-power, giving a speed of 30 knots, but the power was subsequently increased to 70,000 h.p. The armament comprises seven 7·5-in. guns, eight 3-in. quick-firing guns, and four 3-in. anti-aircraft guns, and the vessels are also fitted with six torpedo tubes.

The geared turbine propelling machinery for H.M.S. Raleigh, which was also constructed by Messrs. Beardmore, is illustrated by photographs reproduced on the present and opposite pages. It is of the well-known Brown-Curtis type, having four shafts, each of which is driven by a high-pressure and low-pressure turbine through single-reduction gearing. There is also a cruising turbine directly connected to the forward end of each high-pressure turbine and provided with suitable disconnecting gear, as shown in Fig. 1, on the opposite page. The reduction gearing with the casing removed, and one of the pinions lifted, is shown in Fig. 2, on the same page. As will be seen the usual arrangement, in which the high and low-pressure turbines are placed on opposite sides of the centre line of the propeller shafting, and the pinions of each turbine gear with a single wheel bolted on the shaft, has been adopted; the gearing is of the double helical type. Each shaft is fitted with a Michell thrust bearing supplied with forced lubrication and mounted immediately aft of the gear-box. Some of these bearings are illustrated in Fig. 3 above, while Fig. 4, is a view of the propellers and some parts of the gear case.

As previously mentioned, the machinery, which was originally designed for 60,000 h.p., was subsequently increased in power to 70,000 h.p. To provide for the additional 10,000 h.p. considerable modification was, of course, necessary, both in the arrangement of the boiler rooms and in the details of the turbines. The extra power was obtained, mainly, by fitting additional oil fuel connections to the four boilers in the after boiler room and by modifying the design of the turbine blading, the revolutions being correspondingly increased. The boilers, of which there are 12 in all, are of the Yarrow type, and the working pressure is 235 lb. per square inch. They are arranged in three boiler rooms containing four boilers in each case, but those in the two forward boiler rooms are of a larger type than those in the after room. The eight large boilers are fitted for burning oil fuel only, but the four smaller boilers are arranged to use both oil and coal. It was by altering the proportions of coal and oil burnt in these boilers that the additional power was obtained, as mentioned above. The four sets of turbines are arranged in two compartments. Of these the forward one contains the turbines driving the two wing shafts as well as the necessary auxiliary machinery, while the turbines and auxiliary machinery for the two inner shafts are situated in the after compartment.

On page 344 we reproduce two photographs of H.M.S. Raleigh taken just before the launch. In the bow view, Fig. 5, on page 344, the large flare, necessary to keep the decks dry when running at high speeds in rough weather, is a noticeable feature, and this view also shows the type of crane used in building the ship. Fig. 6, on the same page, is a stern view looking on the starboard side of the vessel. Both views show the modified form of "bulge" used for protecting the vessel against under-water attack.

The other ships of the "Raleigh" class include the Effingham and Frobisher, building at Portsmouth and Devonport, respectively; the Hawkins, recently launched at Chatham; and the Vindictive, formerly the Cavendish. The Vindictive was completed last year by Messrs. Harland and Wolff, and is used as a seaplane carrier.

THE A.C. CUTTING AND WELDING COMPANY, LIMITED: ERRATUM.—In our issue of August 22 last, page 260, we published under the heading "Catalogues" a notice of a publication issued by the above-named firm and by an error referred to the plant described as being workable from a direct-current source of supply. This is not so, the appliances requiring a supply of alternating current, and if a direct-current only is available a rotary converter must be used in connection with the plant.

TWO OLD SCOTTISH CANALS.

The recently issued report of the Commissioners of the Caledonian Canal* contains much interesting matter of a kind which is not usually found in White Papers. The report has also additional interest in as much as, in view of new legislation, it is likely to be the last, and the Commissioners tell quite a romantic story of their 115 years official existence and of the Canals under their jurisdiction.

It was in 1803 that six Commissioners were appointed by Act of Parliament to make and maintain the Caledonian Canal, of which three were ex-officer members. These latter were, rather strangely as we should think nowadays, the Speaker of the House of Commons, the Chancellor of the Exchequer and the Master of the Rolls. The first of their 114 reports dealt with their initial plans and notified the public of the appointment of Mr. Telford as their engineer.

Mechanical appliances were not quite so advanced in 1803 as they are to-day, and the Caledonian Canal, which was then the greatest venture of its kind, was not opened for through traffic from sea to sea until 1822. Even then the capacity did not reach original intentions, various difficulties were encountered (an interesting account of the construction of the canal is given in Smiles' "Lives of the Engineers," Vol. II, Chapter 10), the estimates of the original cost were greatly exceeded, and in an endeavour to finish the canal quickly and economically much inferior work was passed.

Consequently after only 16 years work, the Commissioners were forced to appeal to the Government for a full investigation, by some eminent engineer. The man chosen was Mr. James Walker and as a result of his report, and the recommendations of the Select Committee to whom it was referred, the canal was closed for about four years (1843-7) and repairs carried out at a cost of 192,100*l.* though even these were not entirely satisfactory, inasmuch as, among other things, no proper provision was made for access to works below the water level. Previous to this, however, the Commissioners had extended their sphere of influence by taking over the control of the Crinan Canal, which had been worked by a company ever since 1801, and to which by means of a loan of 19,400*l.* from the Government the Commissioners carried out various repairs. Their position on this respect, however, was an anomalous one and they pressed for its legalisation; which they secured by an Act of 1848, incorporating the Commissioners of the Caledonian Canal, and vesting in them the Crinan Canal, subject to its redemption by the company in twenty years. The *ex-officio* Commissioners were now increased to six, the Master of the Rolls, who must have felt strangely out of place on such a body, being dropped, and four officials more likely to be interested, added, viz., the First Lord of the Admiralty, the Vice President of the Board of Trade, the Lord Advocate and the Member of Parliament for the County of Argyll.

The most serious set back to the Crinan Canal was the bursting of three of the reservoirs in February, 1859, completely filling up the summit with *débris*, breaching the banks in two places, and carrying away some of the lock gates. It cost the Government £15,600 to repair this damage, but the money was well spent, and from the time of its re-opening in 1860 up to 1914 the Crinan Canal was entirely self-supporting. Truly a fine record! The total money spent by the Government up to the war had only been 90,000*l.* on this canal, and 1,242,000*l.* on the Caledonian Canal, while here again right up to 1914 revenue was always considerably in excess of expenditure. Since 1914, of course, war conditions have prevented both canals from meeting current expenditure, though were full credit given to the extensive use which the Admiralty make of the Caledonian Canal, the deficit would be almost negligible. The Commissioners dwell on this point frequently and quote good convincing figures to support their contention. In 1918, for example, the number of passages through the Caledonian Canal was 5,439, of which 1,724 were ordinary passages (chiefly fishing craft) and 3,715 on Admiralty service. The corresponding figures for 1918 were 2,605 total, 2,064 ordinary passages and 54 Admiralty passages. Had these Admiralty passages in 1918 been paid for at ordinary rates, the revenue would have been increased by 13,000*l.* Both canals, however, were able to show small increases in net revenue over the previous years, though as in every other branch of industry and commerce, the high costs of labour and materials have hit the canals hardly.

It is very satisfactory, however, to note that the traffic on the Caledonian was interrupted only on two occasions during the year, owing on the first to the failure of a lock-gate pivot foundation and on the second to floods in Loch Oich, which interfered with the working of a lock; while in the case of the Crinan Canal one stoppage only occurred, when a fall of rock blocked Crinan Reach for three days in January. The report of the engineer, Mr. L. J. Graves, on the state of the piers, wharves, masonary, bridges, lock gates, and attendant vessels, does not make such cheerful reading, and the Commissioners themselves conclude their report by pointing out that canals built 120 years ago must by now be out of date. If they are not improved they must be thoroughly repaired, at a time when materials are becoming increasingly expensive. The cost of conversion into modern waterways suitable for present day traffic has not in the case of the Caledonian Canal, been ascertained. Trial borings were made and plans and estimates prepared for improving the Crinan Canal as long as twelve years ago but the Government has not so far approved the scheme. May we look to the new Ministry of Transport to take the matter seriously in hand?

* One Hundred and Fourteenth Report of the Commissioners of the Caledonian Canal. H.C. 136/19. Price 3*d.*

RAPID REPLACEMENT OF A COLLIERY WINDING ENGINE.

THE Pooley Hall Colliery Company, in continuation of the policy adopted by the directors about eighteen months ago of reconstructing their power-house plant, recently decided to replace their main winding engine by a larger and more economical set. The new engine has cylinders 32 in. and 48 in. diameter, the crank-shaft is 14 in. diameter with main bearings 12 in. diameter and 24 in. long. The engine was built by Messrs. Robey and Co., Limited, of Lincoln, under the supervision of the company's consulting engineers, Messrs. Edwards and Shaw.

The engine had, on account of local conditions, to occupy the same site as that on which the smaller engine was at work, and as the latter was overloaded it was essential that the more powerful engine should be completed at an early date; further the company were most anxious that the period of enforced idleness of the pit should be as brief as possible.

The order for the engine was placed with Messrs. Robey in February, 1919, who undertook to deliver it by July 26, 1919; they kept their undertaking by shunting into the colliery sidings on that day 23 truck-loads of engine parts. The colliery company undertook to dismantle the older engine and to erect the larger set with their own staff, with the aid of three engine erectors supplied by the engine builders, and the other contractors for the steam pipes and auxiliary work.

The alterations to the buildings and foundations were carried out as far as possible, before the delivery of the new engine. The transfer was a very smart piece of work; it was actually completed in twelve days, as the pit ponies were raised to the surface by the old engine on August 2, and the new engine ran under steam on the 14th. About 100 tons of machinery had to be dealt with in the change-over.

The directors allotted 14 days for dismantling the old and the erection of the new engine; the undertaking was a bold one, and was only carried through by every preparation being made beforehand, and the willing co-operation of all concerned. The men of each trade worked in three shifts of 8½ hours, which allowed half-an hour's overlap on each shift to ensure the work proceeding without interruption and to prevent any misunderstanding as to the position on site.

We are informed that a very healthy competition existed throughout between the men on the three shifts, in fact, it was entirely due to the keenness and co-operation of all that the problem was completed within such a short time. The colliery are to be congratulated upon the completion of the work so successfully.

AMERICAN COAL AND COKE OUTPUT.—Railroad labour troubles, says *The Iron Age*, are blamed by the United States Geological Survey for the decrease in the bituminous coal output. Production fell from 9,947,000 net tons for the week ending August 2, to 9,407,000 for the following week. The market is generally improving, but the demand is yet mainly for the better grades of coal, the mines producing the lower grades still reporting time lost because of no demand. The average daily rate of production in the week of August 9 was 1,568,000 tons, compared with more than 2,000,000 tons a year ago. The production of beehive coke continues to increase, the estimates for the week of August 9 placing the output at 383,000 tons, compared with 379,000 tons the preceding week. The gain was almost entirely in Pennsylvania, the other States, except Colorado and New Mexico, recording decreases.

THE COST OF BATTLESHIPS.—The Brussels journal, *L'Echo de la Bourse*, states that the Paris journal, *Le Temps*, dealing with the French naval policy, quotes a number of very suggestive figures. A battleship of a given type costs when built in a private yard between 60,000,000 francs and 64,000,000 francs, the same battleship costing 20,000,000 francs more when built in a Government yard. The director of a French private yard who was on the point of undertaking the construction of certain warships for a foreign Government, on being asked how he established his cost price, replied that the matter was very simple; he always based his calculations on the budget of the navy, as he knew that in that way he was always on the safe side. The Government arsenals, therefore, in a way regulate the cost of ship construction, but they make for a maximum figure and not for a minimum one.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Tuesday.

Iron and Steel.—Inquiries show that though tempting offers made by foreign manufacturers respecting semi-manufactured materials are resulting in actual purchases locally at comparatively low prices, export trade in manufactured goods is improving materially. Despite high costs and transport delays, local iron and steel-masters have secured several valuable orders for re-constructive engineering work on the Continent, and for the supply of railway material and locomotive parts. If a minor part of the inquiries in circulation materialise in contracts with South Yorkshire concerns, an active future will be assured. The restriction of naval building has aimed a serious blow at the heavy trades of Sheffield, where many large rolling mills and mammoth presses have for several years been exclusively employed on armament work of a large type. Special schemes are in hand to cater alternatively for an increased share of transport construction work, and there is little doubt that Sheffield will ultimately attain a comparative fame in this connection. Meanwhile engineering organisers have been compelled to suspend a good deal of highly skilled labour, but there is little doubt that it will gradually be absorbed as the new schemes get under weigh, and that extensive unemployment will be avoided. Special experiments are being undertaken to reorganise marine work on lines of greater productivity, including the rolling, instead of forging, of marine shafts. The raw material market shows several uneven features. Basic iron cannot be bought in the quantities required of local producers, who declare that quotations, even as recently revised, are uneconomic. There is a strongly-supported rumour that a large number of furnaces in the Derbyshire district will confine their output to foundry and forge sorts. Deliveries of hematites are rather more satisfactory. West Coast hematites are quoted at 10*l.* 12*s.* 6*d.*, and East Coast at 10*l.* 6*s.*, but purchases have been made below those figures. Similarly, Lincolnshire basic, offered at 8*l.* 12*s.* 6*d.*, has been bought at a reduction of 4*s.* to 5*s.* South Yorkshire bars are officially quoted at 22*l.* 10*s.*, but pressure on supplies is so great that substantial premiums are offered for immediate delivery. In striking contrast, American bars are offered delivered locally at 19*l.* 10*s.*, and Belgian bars at 1*l.* less. The lighter trades are organising for increased output by the wider adoption of grinding machinery, which, in the file section, has proved an unqualified success.

Hull Coal Traffic.—A big shrinkage is recorded in the returns for August. The receipts for the month dropped, as compared with the corresponding month of last year, by 134,765 tons, to 97,791 tons, while the total for the eight months declined by 431,870 tons, to 1,368,601 tons, as compared with 1918. The only substantial improvements recorded were in the case of the Grimethorpe and Frickley Colliery, which sent 5,988 tons during the month as compared with 5,590 tons in August, 1918, and Mansfield Colliery, which sent 2,077 tons as against 1,048 tons.

South Yorkshire Coal Trade.—Scarcity of wagons is the chief drawback to expansion of trade. Traders complain that wagons are kept locked up in railway sidings and cannot be loaded, and that journeys are occupying abnormal periods. Pressure is being exercised on all hands to expedite deliveries. Home consumers of best steam coals are replenishing depleted stocks very slowly. The call for cobbles, nuts and slacks is much in excess of the supply. A similar state of affairs obtains in the household section. Merchants are being bombarded with orders which they cannot execute. Winter stocking arrangements are badly in arrear. Quotations:—Best branch hand picked, 33*s.* to 34*s.*; Barnsley best Silkstone, 33*s.* to 33*s.* 6*d.*; Derbyshire best brights, 31*s.* to 32*s.*; Derbyshire house coal, 28*s.* 6*d.* to 29*s.*; Derbyshire best large nuts, 28*s.* 6*d.* to 29*s.* 6*d.*; Derbyshire small nuts, 27*s.* 6*d.* to 28*s.* 6*d.*; Yorkshire hards, 28*s.* 6*d.* to 29*s.* 6*d.*; Derbyshire hards, 28*s.* 6*d.* to 29*s.* 6*d.*; best slacks, 24*s.* 6*d.* to 25*s.* 6*d.*; nutty slacks, 23*s.* to 24*s.*; smalls, 19*s.* to 20*s.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—There is a quieter feeling in Cleveland pig-iron, but values are upheld. It is still difficult to purchase foundry quality for prompt delivery, though pressure for supply of that grade of iron is distinctly easier on home account, most consumers having made contracts to cover their needs as far ahead as they care to commit themselves at present. Distribution is still hampered by shortage of trucks. Demand on Continental account is unabated, foreign customers being apparently keen to place orders at current rates. Shipments abroad are on a moderate scale, and expansion of foreign trade is looked forward to with some confidence as there is promise of more iron becoming available to load for despatch to Continental ports, and there is likelihood of export licences being less difficult to secure. Forge iron is being taken up better, but the supply is still abundant. For home consumption, No. 3 g.m.b. and No. 4 foundry stand at 160*s.*, No. 1 is 164*s.* and No. 4 forge ranges from 157*s.* to 160*s.*; whilst export rates are 5*s.* above these quotations.

Hematite Iron.—Supply of East Coast hematite is more plentiful. Home consumers are now fairly comfortably placed, most of them having made preparation for their requirements over the next few weeks. The volume of export trade, however, is still officially restricted, though demand from abroad is on a by no means extensive scale. Nos. 1, 2 and 3 are 200*s.* for

home purposes, and 205*s.* for export; and No. 1 is 202*s.* 6*d.* for home use and 207*s.* 6*d.* for shipment to foreign ports.

Foreign Ore.—There is little or nothing passing in foreign ore just now. Consumers continue to hold aloof from the market, and they are not likely to come forward to buy until the position changes a good deal, for not only are they carrying considerable stocks, but they are receiving regularly good deliveries against the substantial contracts they have made. Imports, however, may show some falling-off in the near future, as indications are not wanting of tonnage becoming less plentiful. Freights are consequently stiffening, but doubtless steamers Bilbao-Middlesbrough could still be fixed at 25*s.* Rubio, of 50 per cent. quality, remains in the neighbourhood of 53*s.* 6*d.* c.i.f. Tees.

Coke.—Coke is certainly less scarce than it has been, but the shortage is still pronounced. Medium blast-furnace kind is readily snapped up at the full price of 48*s.* at the ovens, and low phosphorus sort commands 49*s.* 6*d.* at the ovens.

Manufactured Iron and Steel.—In finished iron and steel, manufacturers generally are busily employed, but, so far as can be ascertained, they are booking few forward contracts, except in the sheet department, where heavy orders have been placed. Export prices continue matter of negotiation, but may be given as rather above the following, which govern the home trade:—Common iron bars, 22*l.*; marked bars, 24*l.* 10*s.* to 25*l.*; steel ship, bridge and tank plates, 18*l.* 5*s.*; steel angles, 17*l.* 15*s.*; steel joists, 17*l.* 10*s.*; steel hoops, 24*l.* 15*s.*; heavy sections of steel rails, 16*l.* 10*s.*; black sheets, 24*l.*; and galvanised sheets, 30*l.*

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—Little change has taken place in the conditions ruling in the Scotch steel trade during the past week and much activity continues all round. Bookings have been very satisfactory, and makers are well placed for the present and the near future, and with each week bringing along new specifications to cover deliveries it looks as if the present state of activity would last right on to the end of the year at any rate. So long as the home consumer demands so much stuff the amount available for export must remain very small indeed. The threat of competition from the Continent is not considered as likely to be of great seriousness for a bit on account of the rising tendency of prices abroad, and when real competition commences the home makers will be in a position to face it. The demand for ship and boiler plates is still very great and consumers keep pressing for supplies, but in the case of sectional material there is plenty of stuff to go round. Makers of steel sheets are well placed with orders, particularly for the heavier gauges, and plants are being kept running steadily. The export trade is not of very heavy proportions yet because of home demands, but a fair amount is going through. Prices are unchanged and continue firm with those for export at 21*l.* to 21*l.* 10*s.* per ton for ship plates, and 24*l.* 10*s.* per ton for boiler plates.

Malleable Iron Trade.—Malleable iron makers in the West of Scotland are very busy and orders booked amount to quite a satisfactory tonnage. The bulk of the business is for home consumption and export lots are not of any great moment owing to the high prices. Horse-shoe iron is in good demand, and large deliveries are general. Prices are unchanged, and are based on 21*l.* 12*s.* 6*d.* per ton, net, Glasgow, for "crown" bars.

Scotch Pig-Iron Trade.—One of the outstanding features of the Scotch pig-iron trade is the continued demand for hematites. This state has now lasted for many months and there is no signs of it easing, in fact, the pressure for deliveries is as great as ever and the local steel makers keep consuming very large quantities of it. Forge iron is more plentiful and no delay takes place in deliveries. Foundry iron is in good request, and as there is more available at the present time consumers are not now kept waiting. No alterations have been made in current prices, which remain on the present high level, with no sign of weakening.

General Trade.—Throughout the industrial part of Scotland the engineering and allied trades are nearly all in a flourishing condition and prospects are quite satisfactory. Most industrial concerns are well booked forward, and activity is assured generally for months to come. Shipbuilders are working steadily, and many launches will be noted up against this month, while contracts on hand represent a heavy tonnage. Boiler makers are also very busy and could turn out more work were the supply of plates better, as present deliveries go rapidly into consumption. General engineering firms have lots of work to do and have kept their establishments running at full pressure.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Markets.—There is no appreciable alteration in the coal market. The tonnage position is still pretty good, though arrivals of late have diminished owing to owners, chiefly foreign, having diverted their vessels to other ports because of the recent congestion. Collieries generally are fairly well stemmed and have sufficient orders to keep them busy. Congestion in regard to loading hoists is, however, creating difficulties and complaints are heard of slackness on the part of the coal trimmers in trimming cargoes under the pooling scheme, which came into operation last month. On a particular night last week only 48 wagons were tipped at five tips in the Cardiff docks, an average of about 1¼ trucks per hour, or approximately 12½ tons, as the average load of each truck is 10 tons. As outputs in the coalfield are increasing, having reached over 970,000 tons in the week ending August 23, it is feared that, unless the tipping capacity of the various docks are speeded up, temporary stoppages will have to be made at collieries owing to a lack of trucks. In July last the Railway Executive Committee ordered railway companies to keep collieries supplied with wagons, and this instruction has now been cancelled and the supply of common user wagons withdrawn. Prices are not so high as they were a fortnight ago, and have developed an irregular tendency. Some sellers are still asking 85*s.* for the best large coals, but concessions of from 2*s.* 6*d.* to 5*s.* can be secured by buyers able to take immediate delivery. Small steam coals are more plentiful than for some time past, especially the inferior qualities which can be secured from 40*s.*, ordinaries up to 55*s.*, and best descriptions round 60*s.*, though some collieries are still asking 65*s.* for the latter. Bituminous sorts are steady, with No. 2 Rhondda large round 75*s.* and No. 2 throughs round 65*s.* Coke is scarce and firm at 105*s.*, and the same remark applies to patent fuel, which is worth 85*s.* Pitwood continues plentiful on the basis of 75*s.*

Newport.—Large Monmouthshire coals are more plentiful with prices steady round 82*s.* 6*d.* for the better qualities and from 77*s.* 6*d.* to 80*s.* for the cheaper grades. Smalls range from 45*s.* to 55*s.*, according to quality, and concessions are possible in isolated cases for quick shipment.

Bunker Coals for Coasting Steamers.—It was reported last week that the South Wales coalowners had abandoned their proposal to arrange a schedule of fixed prices for coals supplied to British steamers in the United Kingdom coasting trade for bunker purposes. Contrary to expectations, however, the coalowners have agreed to supply these particular vessels with bunkers at a fixed price of 20*s.* per ton above the schedule A minimum prices, making best large coal 66*s.*, against the current market price of 85*s.*, and best small steams 54*s.* 6*d.*, compared with the market value of 62*s.* 6*d.* Arrangements have now been completed for bunkering steamers at Liverpool with seaborne South Wales coals instead of Lancashire, Yorkshire and North Wales coals, which will now be used for manufacturers and works purposes. A committee has been set up in Liverpool to deal with deliveries which approximate 40,000 tons per week, and similar organisations are to be set up in Hull, Newcastle and Glasgow to control the bunkering of steamers.

INCOMPLETE CATALOGUES.—The British Consul at Paramaribo, Dutch Guayana, calls the attention of United Kingdom firms to a complaint made by traders against the practice of sending unpriced catalogues from the United Kingdom, which has, in several instances, resulted in the loss of trade. He points out that instances have occurred in which orders have been lost because certain catalogues contained no indication of prices.

AMERICAN BLAST FURNACES FOR INDIA.—The American Press reports that two blast furnaces are to be sent from the United States to the Tata Iron and Steel Company, at Jamshedpur, near Bombay, India. A charcoal blast furnace is also being prepared for the State of Mysore, India, and a contract has been accepted to supply a 350-ton blast furnace for the Indian Iron and Steel Company, to be erected 125 miles from Calcutta. The latter company proposes to erect three blast furnaces, by-products coke ovens, benzol plants and a modern open-hearth steel plant and finishing mills.

PERSONAL.—Mr. W. H. Dugdale, M.Inst.C.E., of Sunderland, who, on Friday last, the 5th inst., was unanimously elected president of the Shipbuilding Employers' Federation at a meeting at Edinburgh, is the managing director of Messrs. Austin and Son, Limited, shipbuilders, Sunderland. He is a past-president of the North-East Coast Institution of Engineers and Shipbuilders, a past-president of the Sunderland Chamber of Commerce, chairman of Lloyd's Technical Sub-Committee and a member of the Institute of Naval Architects. He also holds the position of chairman of the Wear Shipbuilders' Association, and is chairman of the Works Committee of the River Wear Commission.

QUEENSLAND WOLFRAM.—The largest wolfram producing properties in the world are being acquired by the Burma Queensland Corporation, which is taking over from Thermo Electric, Limited, 98·98 per cent. of the issued capital of the Tavoy Concessions, Limited, proprietors of the well-known Hermyingoi wolfram and tin-mining properties, and other similar mines at Tavoy, Burma, comprising an area of over 10 sq. miles. The corporation is also taking over the Queensland mines, Wolfram Camp and Mount Carbine, comprising an area of 278 acres, which have been the main source of the world's supply of molybdenite. The interest in the Burma properties and the Queensland properties was acquired for 118,000*l.* cash, 250,000 fully-paid debenture stock, and 430,000 fully-paid shares of the corporation. The Queensland properties have been equipped with modern plant and machinery, costing 197,000*l.*, and production with this plant was commenced in February last. The annual profits, on the basis of pre-war prices for tin, wolfram, molybdenite and bismuth, are estimated as follows: Burma properties, 50,000*l.*; Wolfram Camp 40,000*l.*; Mount Carbine, 12,000*l.*; total, 102,000*l.* The amount required for the yearly service of the debenture stock is 57,000*l.*, leaving an estimated margin of profit in excess of stock requirements of 57,000*l.*

NOTICES OF MEETINGS.

JAMES WATT CENTENARY COMMEMORATION, BIRMINGHAM.—The programme will commence on Tuesday, the 16th inst., at 10.30 a.m., with a lecture by Professor Burstall, followed at 11.30 a.m. by a lecture by Professor Hele-Shaw. At 2.30 p.m. there will be a memorial service at Handsworth Parish Church, and at 4 p.m. a garden party at Heathfield Hall. In the evening, at 8 p.m., there will be a reception and conversazione by the Lord Mayor, at the Council House. On Wednesday, the 17th inst., a lecture will be delivered by Sir Oliver Lodge, at 10.30 a.m., and at 11.15 a.m. there will be lectures by Professor A. Barr and Professor J. D. Cormack. At 2 p.m. a visit will be paid to the engine at Ocker Hill, near Wednesbury, or to the two Watt engines at Bordesley (dated 1796) and Lawley-street (dated 1817); the latter engine will be under steam. At 8 p.m. the Centenary Dinner will be held. On Thursday, the 18th inst., a visit will be paid to the Soho Foundry of Messrs. W. and T. Avery, Limited, at 9.45 a.m., and at 11.15 a.m. degree congregations will be held at the University of Birmingham. At 2 p.m. visits may be paid to Watt engines as detailed above for the previous day, or an alternative excursion to Stratford-on-Avon may be made. On either Wednesday afternoon or Friday, the 19th inst., visits may be made to the works of the following firms: Messrs. Cadburys, Bourneville; the Birmingham Small Arms Company, Limited; Messrs. Bellis and Morcom, Limited; Messrs. E. G. Wrigley and Co., Limited; or Messrs. Elkington and Co.

THE IRON AND STEEL INSTITUTE.—The Autumn Meeting will be held in the House of the Institution of Civil Engineers, Great George-street, Westminster, on Thursday and Friday, September 18 and 19. Thursday, September 18: 10.30 a.m., General Meeting of Members; award of the Bessemer Medal for 1919 to Professor Cav. Federico Giolitti, Ph.D. of Turin. 11 a.m. and 2.30 p.m., General Conference on Fuel Economy, under the auspices of Committee No. 1 on Fuel and Ores, at which reports and papers will be read by Dr. W. A. Bone, Sir Robert Hadfield, Bart., Mr. A. Hutchinson, Mr. H. J. Yates, and by Messrs. Cosmo Johns and L. Ennis. Friday, September 19: 10 a.m., General Meeting of Members; papers Nos. 10, 13 and 4 will be read and discussed. 2.30 p.m., Afternoon Session; papers Nos. 1, 11, 6, 9 and 8 will be read and discussed. The following is the list of papers that are expected to be submitted: (1) Mr. J. H. Andrew, Mr. J. N. Greenwood and Mr. G. W. Green, "Nickel Chrome Forgings"; (2) Mr. W. A. Bone, Sir R. A. Hadfield, Bart., and Mr. A. Hutchinson, "Report on Fuel Economy in Steel Works" (with a supplementary report by Mr. H. J. Yates on "Fuel Economy in Foundry Practice"); (3) Mr. E. D. Campbell, "Decarburisation of Steel"; (4) Mr. J. J. Cohade, "On the Woody Structure of the Fractures of Transverse Test Pieces from Special Steels"; (5) Mr. Cosmo Johns and Mr. L. Ennis, "Fuel Economy in German Iron and Steel Works"; (6) Mr. R. H. Greaves, "Temper Brittleness of Nickel-Chrome Steel"; (7) Mr. K. Honda, "Nature of the A 1 Transformation and a Theory of Quenching"; (8) Mr. K. Honda and Mr. H. Takagi, "On the Cause of Irreversibility in Nickel Steels"; (9) Mr. N. Hudson, "Experiments with Nickel Steels"; (10) Mr. C. A. Keller, "Synthetic Cast-Iron"; (11) Mr. F. Rogers, "Brittleness in Nickel-Chrome and other Steels"; (12) Mr. T. Murakami, "On the Structure of Iron-Carbon-Chromium Alloys"; (13) Mr. J. H. Whiteley and Mr. A. F. Hallimond, "The Fluxing Action of Iron Oxides on Acid Furnace Structures."

ELECTRIC CONDUCTIVITY OF MOLTEN SEALING WAX.—Sealing wax is not an exception to the rule that insulators conduct the current at high temperatures. In order to demonstrate this conductivity a drop of fused sealing wax may be taken up with a stout wire and the wire be suspended from one of the terminals of an electric machine of the Toepler or Wimshurst type. As the sparks pass, pointed excrescences begin to form on the wax and to grow into long hairy filaments. The filaments repel one another and finally break up into small drops, which can be caught on paper. In a paper which the veteran physicist, Professor G. Quincke, of Heidelberg, publishes in the *Annalen der Physik* of April 25 last, he suggests that the behaviour of molten sealing wax under strong electrification is analogous to that of the volatilisation of metals by powerful discharges, and that the heterogeneous character of sealing wax plays an important part in the phenomenon. In his experiments he coated short stout wires with sealing wax and made the wire one of the terminals, or he attached a large drop of sealing wax to the end of an insulated wire, which he exposed to powerful sparks. The sealing wax was then jerked off in ribbons, tubular at one end, pointed at the other, and in fine threads. Examined by the aid of the polarising microscope the ribbons showed raised edges and doubly-refracting cross ridges; the threads proved wavy with constrictions, and broke up into little spherules. Sealing wax is prepared by fusing shellac or some other resin with some powdered mineral material. According to Quincke, the electrified sealing wax has a lower melting point than the unelectrified; the fused sealing wax is a conductor of electricity, and in the fused mass the fine mineral particles are driven by the electric forces to the edges of the ribbons. Sealing wax has the "foam structure" of commercial metals, in which lamellæ, consisting of the more impure constituent, and solidifying first when the fused metal cools, form the walls of the cells in which the purer metal itself solidifies at a later stage. Quincke suggested this foam structure in a series of papers many years ago and summarised his views in 1912 in the *Internationale Zeitschrift für Metallographie.*

H.M.S. LIGHT CRUISER "RALEIGH."

CONSTRUCTED BY MESSRS. WILLIAM BEARDMORE AND CO., LIMITED, DALMUIR.

(*For Description, see Page* 341.)

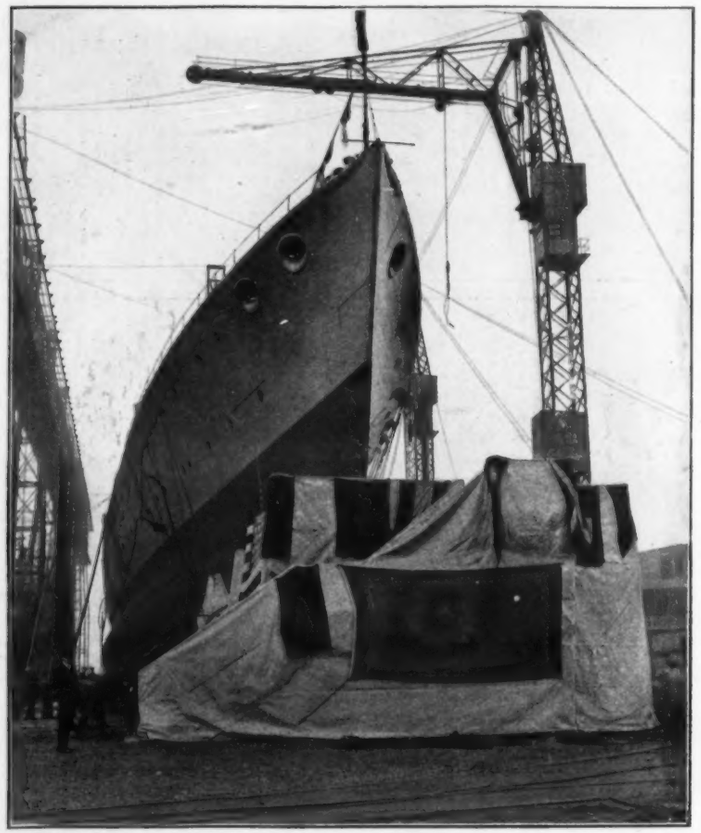


FIG. 5.

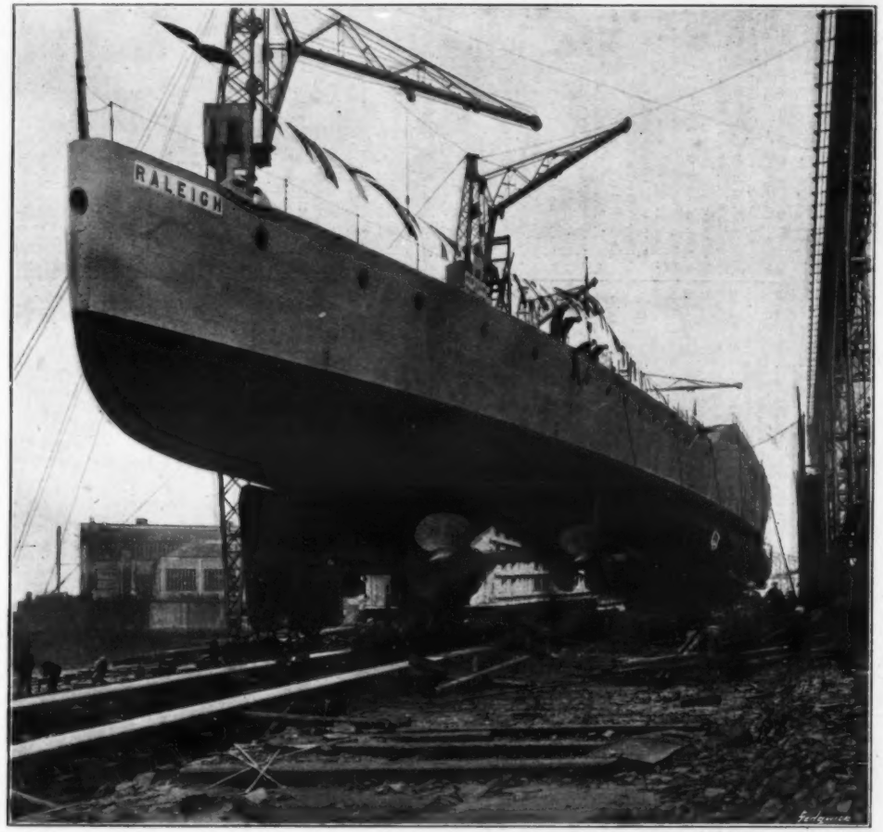


FIG. 6.

WHITE STAR LINE JUBILEE.—The White Star Line celebrated a few days ago its fiftieth anniversary, the Oceanic Steam Navigation Company, Limited, to give it its official title, having been registered on September 6, 1869. Prior to that date the familiar house flag had flown at the masthead of many a smart Australian clipper; but in 1867 the late Mr. Thomas Henry Ismay took over the flag from the then owners and very shortly signalised the acquisition by substituting iron ships for the wooden vessels formerly employed. Two years later Mr. Ismay deemed the moment ripe for the introduction into the Liverpool and New York trade of a high-class passenger service, and induced some friends to support him in the formation of the Oceanic Steam Navigation Company, Limited, the original capital of which was 750,000*l*. In the following year he was joined in partnership by the late Mr. William Imrie, formerly of Imrie, Tomlinson and Co., in whose office he and Mr. Imrie had been fellow apprentices; and Ismay, Imrie and Co. became managers of the White Star Line, continuing to act in that capacity until 1913. In 1902 the White Star Line was affiliated with other leading steamship companies in the North Atlantic trade, viz.: British and North Atlantic Steam Navigation Company, Limited, International Navigation Company, Limited, Atlantic Transport Company, Limited, Société Anonyme de Navigation Belge-Americaine (Red Star Line) and Frederick Leyland and Co., Limited, in forming the International Mercantile Marine Company. Under the new *regime* there was no slackening of the bold policy hitherto adopted, the company establishing a passenger and freight service between the United States and Mediterranean ports in the following year, whilst adding to its operations from Liverpool by initiating the despatch of high-class steamers thence to Boston and elsewhere. Thus far, Liverpool had served as the English port of departure and arrival of the company's New York service, but experience showed that Paris was as much the objective of the American traveller as London, and, consequently, the managers of the White Star Line transferred their mail service from Liverpool to Southampton in 1907, continuing, however, to maintain a weekly service of twin-screw passenger steamers between the Mersey port, Queenstown, and New York. The Adriatic inaugurated the new service between Southampton, Cherbourg, Queenstown and New York, the homeward voyage being made *via* Plymouth and Cherbourg, and by such means an opportunity was afforded for American travellers to disembark either at an English or a French Channel port. This departure was successful from the start, and the service was originally operated by the Adriatic, Oceanic, Majestic, and Teutonic, whilst the Baltic, Cedric, Celtic and Arabic were the steamers maintaining the Liverpool, Queenstown and New York weekly passenger and cargo service. In 1909 the White Star Line combined with the old-established Dominion Line in forming a joint service from Liverpool to Canada. During the war, the company's losses in ships were heavy, testifying to the world-wide operations performed under most dangerous circumstances; and, if the Olympic's deeds attracted more special notice by their brilliance, the services rendered by other vessels of the fleet also upheld the honour of the house flag and of that greater flag cherished by all.

THE BRITISH TANKS USED IN THE WAR; MARK IV.

(For Description, see Page 334.)

Fig. 5.

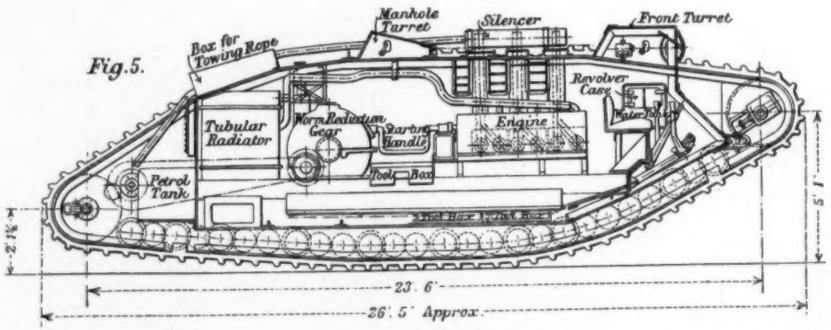


Fig. 6.

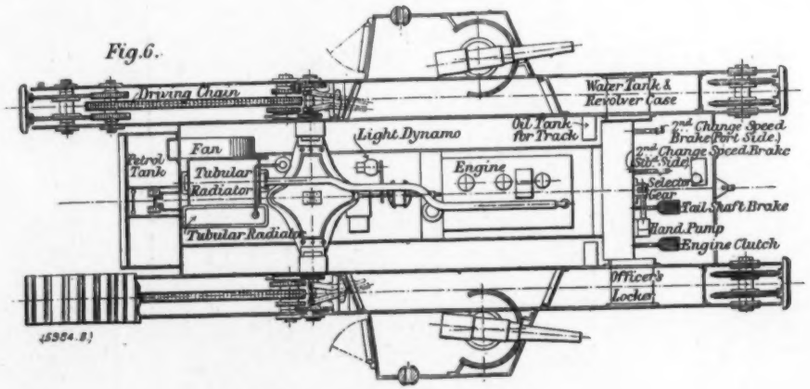


Fig. 7. FRONT VIEW.

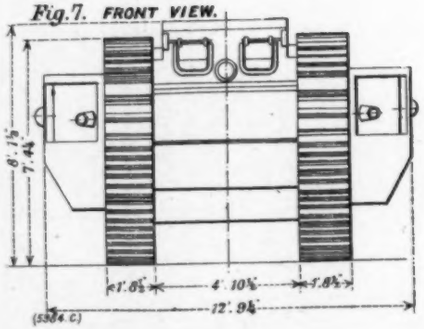


Fig. 8. The Tank in Action.

Fig. 9. A Tank after the Action.

THE BRITISH TANKS USED IN THE WAR; MARK V.

(*For Description, see Page* 334.)

FIG. 10. THE TANK IN ACTION.

Fig. 11

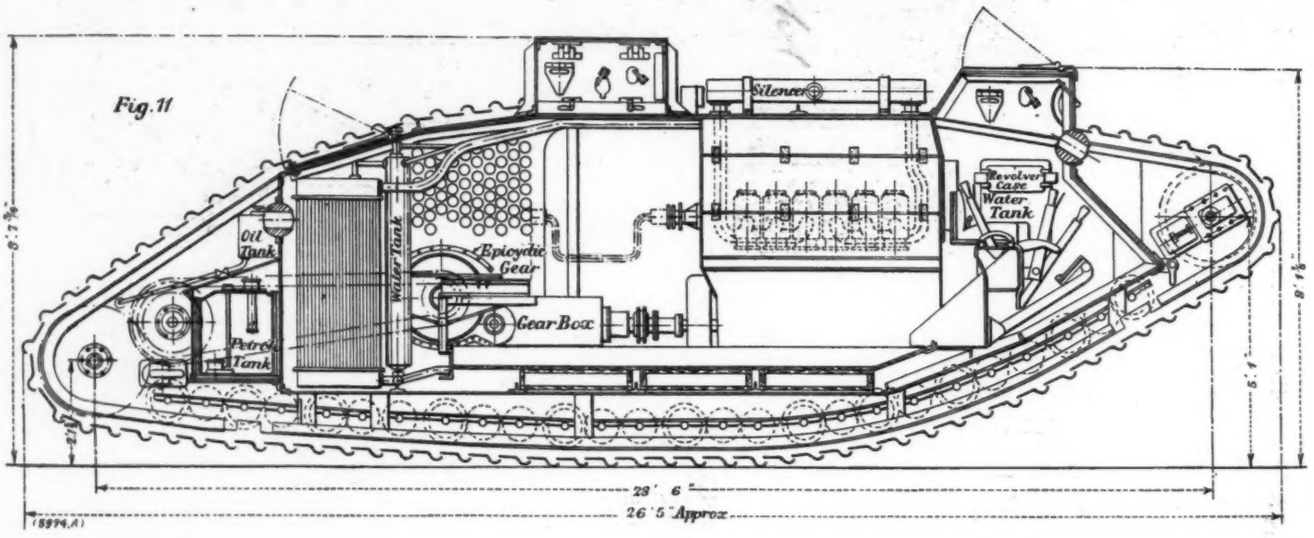
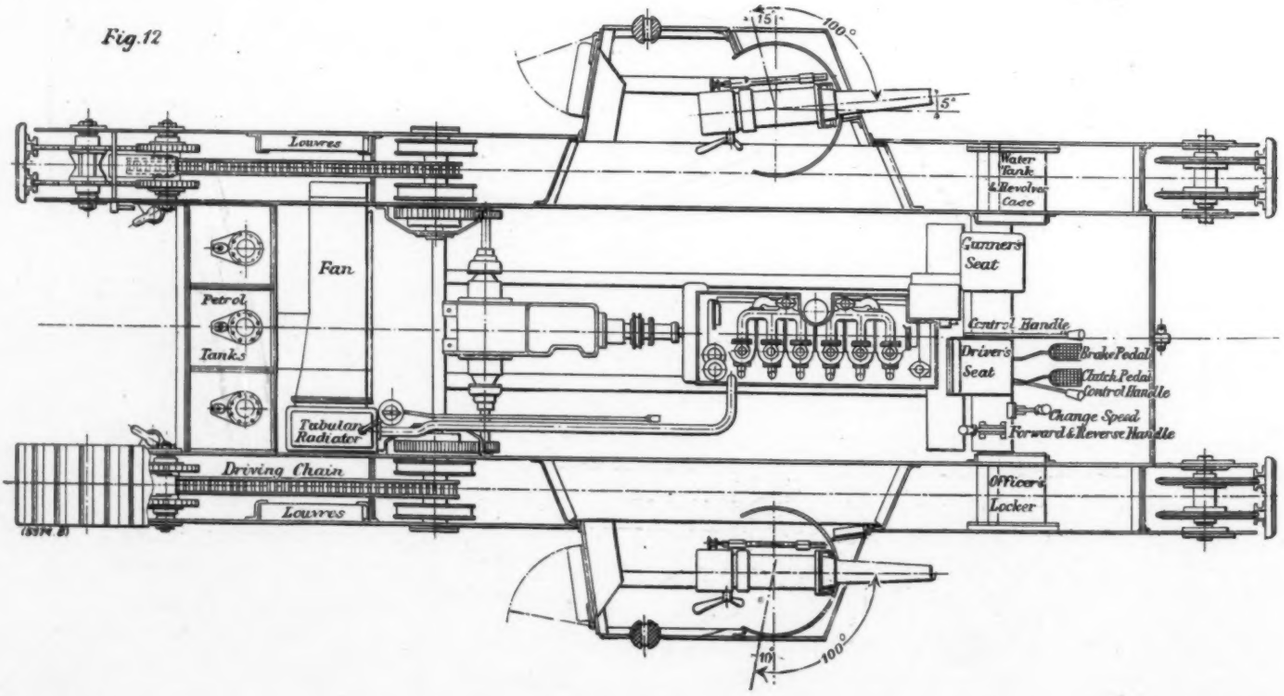


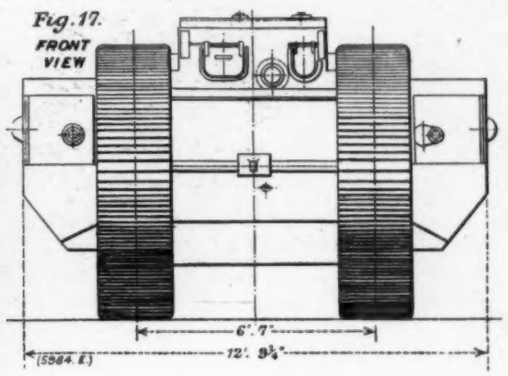
Fig. 12

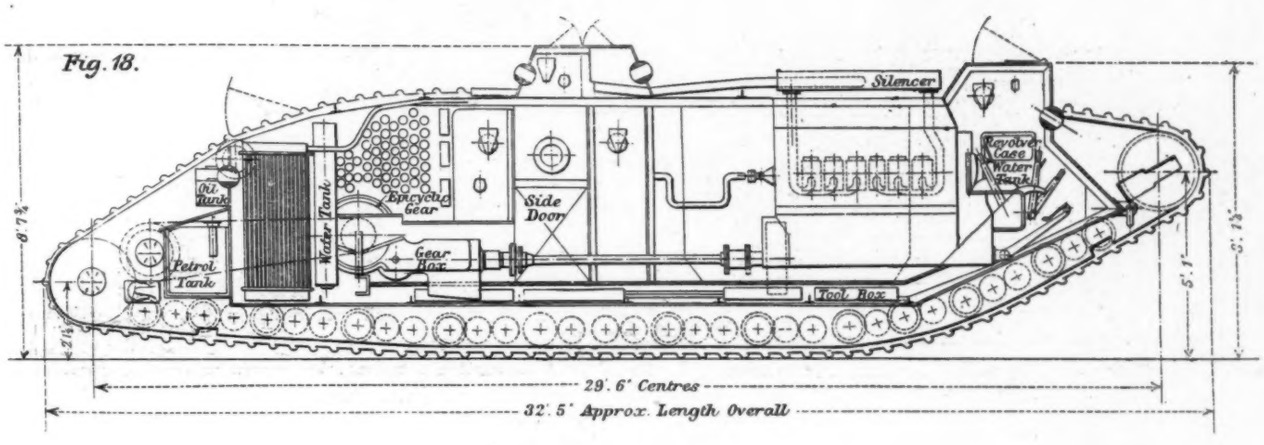


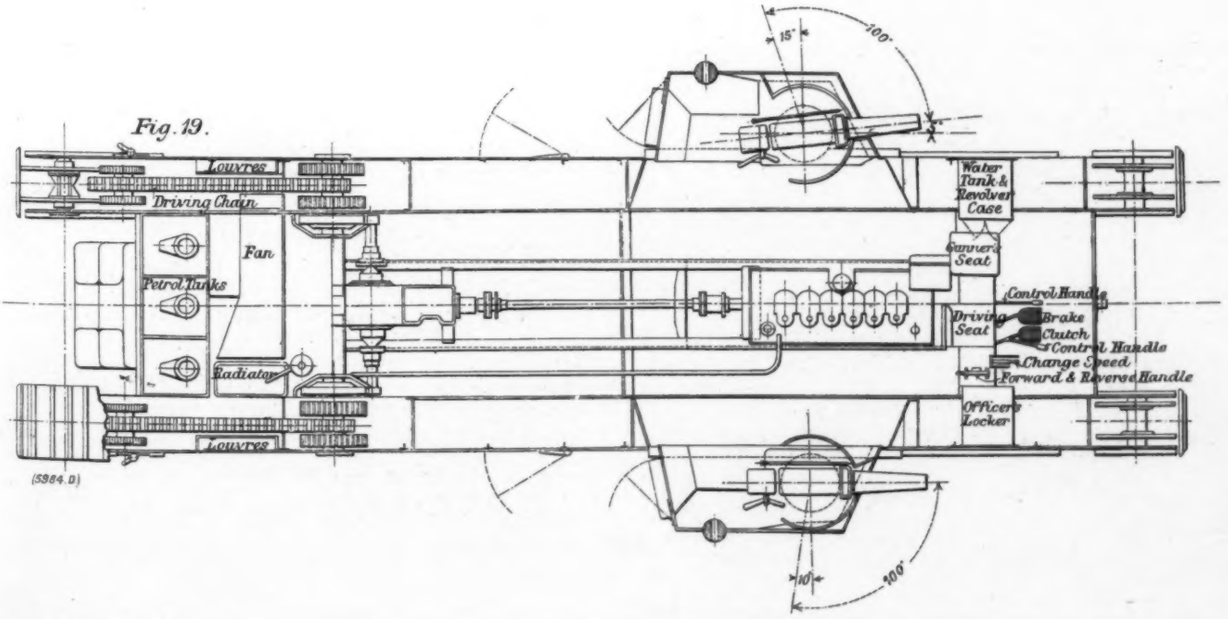
THE BRITISH TANKS USED IN THE WAR; MARK V*.

(*For Description, see Page* 334.)

FIG. 16. THE TANK IN ACTION.







THE BRITISH TANKS USED IN THE WAR; MARK VII.

(For Description, see Page 334.)

Fig. 23.

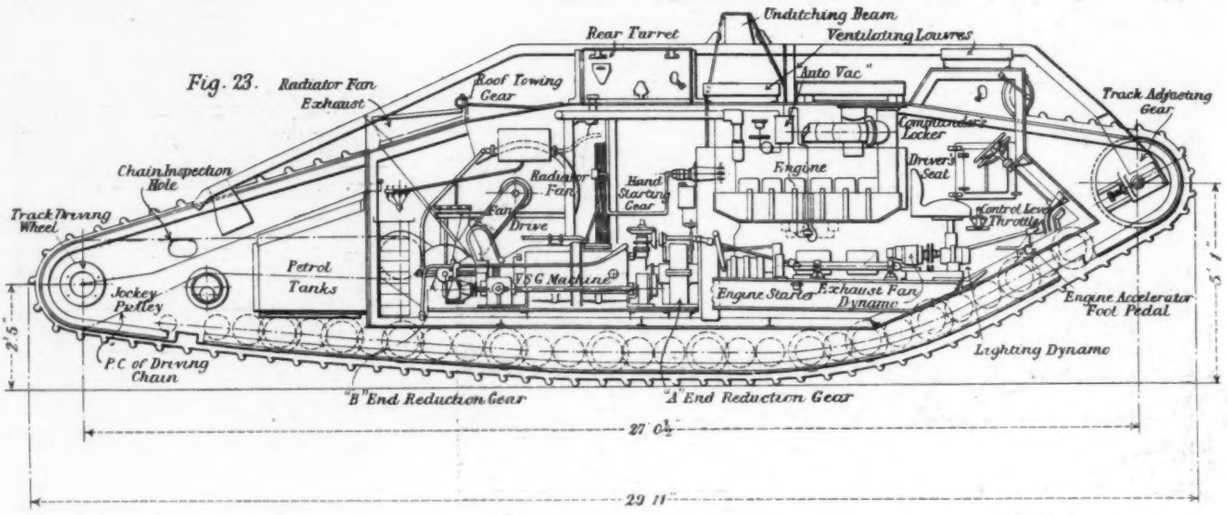


Fig. 24.

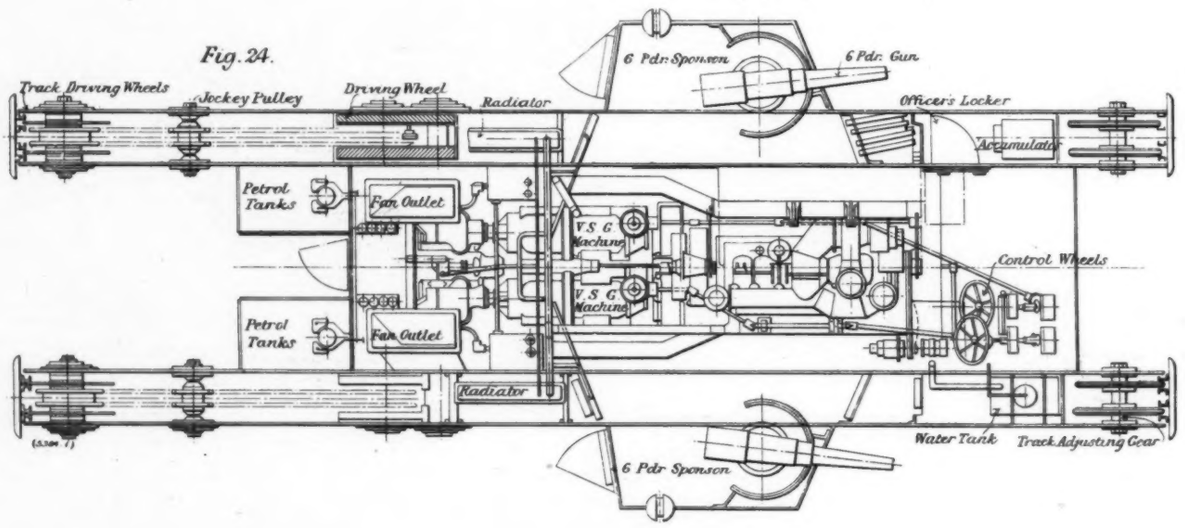


Fig. 25.

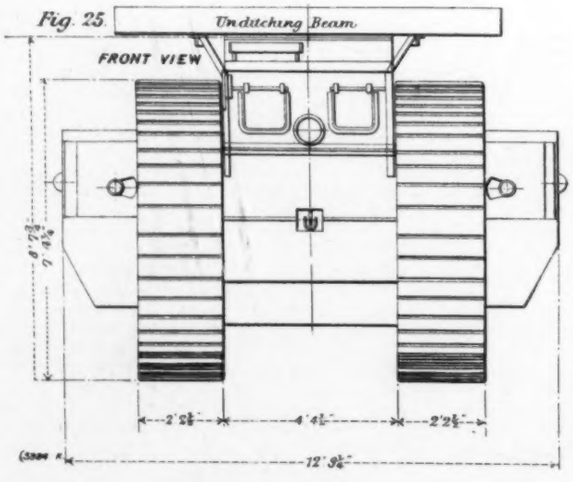
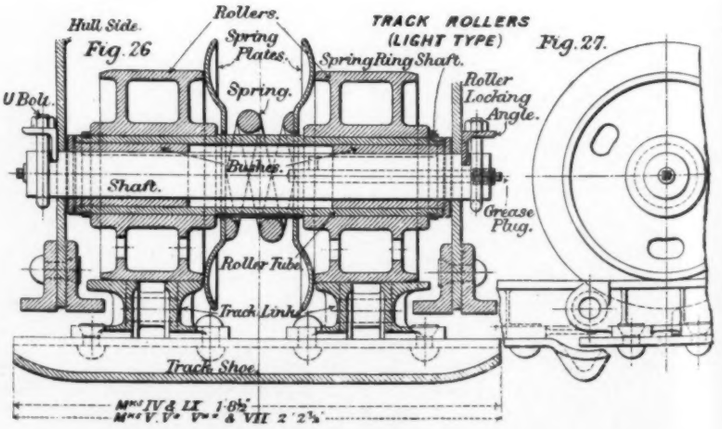


Fig. 26.



TRACK ROLLERS (LIGHT TYPE)

Fig. 27.

(To face page 337.)

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We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.

TELEPHONE NUMBERS—9683 and 8568 GERRARD.

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NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions still imposed by the Government on the importation of paper and the consequent shortage of Supplies, Newsagents will not have copies for chance customers: therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 343.

ENGINEERING.

FRIDAY, SEPTEMBER 12, 1919.

THE CONDITION OF IRONWORKS ON THE CONTINENT.

As the result of her attack upon France in 1870, Germany obtained possession of the valuable ore deposits of Lorraine, and her pre-eminence in iron and steel manufacture on the Continent was largely due to her ownership of this territory. Her next onslaught, five years ago, was marked at its outset by the seizure of Belgium, a move which placed practically the whole of the coal mines, blast furnaces and ironworks of the Continent under German control. Our European Allies, deprived thus of the physical basis of defence, were forced to rely upon Great Britain and America for munitions, but in due course the wave of invasion was thrown back, and to-day the rightful owners are once more in possession. Not only this, but an Allied Army of Occupation holds the banks of the Rhine and the Saar Valley in Rhenish Prussia as a security for the faithful fulfilment of the conditions of peace, so that at the present time the Continental iron and steel industry is virtually under Allied ownership or supervision.

The increased production of iron and steel is essential to the recovery of the economic life of Europe, for until an adequate supply is forthcoming, transportation by land and sea is hampered, restoration of the devastated regions is delayed, and manufacturing of every kind is impeded. The first desire, therefore, of all who wish well to the Allied countries, including Great Britain, is that the French and Belgian ironworks should return as soon as possible to the highest degree of productivity. For this reason we have a direct interest in the condition in which the plants have been left by their temporary masters, as well as in the other circumstances which will affect the revival of their activities. We know, moreover, that when the present shortage of iron and steel is overcome and supply once more approaches demand, we shall ourselves have to meet these plants in friendly competition, so that from every point of view we are interested in their conditions and equipment. The appearance, therefore, of the "Report of the Commission appointed to examine the conditions of the Iron and Steel Works, in Lorraine, in the occupied areas of Germany, in Belgium and in France" is very opportune. The Commission was sent out in April of this year and returned early in May. In view of the extent of the ground to be covered in the short time at their disposal, the members of the Commission divided themselves into two parties. The first party, in charge of Sir William J. Jones, K.B.E., of the Ministry of Munitions, was composed of Messrs. Percy S. Cooper, of the Partington Iron and Steel Company, Roland C. Harding, of Messrs. Robert Heath & Sons, Limited, and Cosmo Johns of Messrs. Vickers, Limited. This party inspected some 14 blast-furnaces and steel-works, mostly in the Metz-Briey-Thionville district, and apparently must have had a very strenuous time. The second, or Cologne, section of the Commission was in charge of Dr. F. H. Hatch, of the Ministry of Munitions, and comprised Messrs. L. Ennis, of Messrs. Dorman, Long & Co., Limited, James Henderson, of the Frodingham Iron and Steel Company, Limited, and Richard Mather, of the Research Department, Woolwich Arsenal. This section visited 19 works altogether at Cologne, Crefeld, Longwy, Liége, Charleroi and other places, including Kruppe' establishment at Rheinhausen, and the Felten and Guillaume works near Cologne. As in the case of their fellow-members of the Commission, they most certainly cannot be charged with any want of energy. Both parties were accompanied by officers representing military interests.

The terms of reference of the Commission were wide, but definite. Its duty was to report upon (*a*) the technical and other developments during the war; (*b*) the present conditions of plant and machinery; (*c*) the possibilities of the areas in question as competitors with, or markets for, British industry; (*d*) the developments in fuel economy. It was unanimously decided that the best way in which the terms of reference could be fulfilled was by describing the lay-out and equipment of each works, noting all points likely to be of interest or importance. This was done, and the Report, therefore, consists principally of a series of descriptions of works, together with the conditions obtaining at each, so that the reader has the evidence at hand to support the general deductions drawn as to the state of the industries. We may clear the ground at the outset by stating that the damage suffered by the various iron and steel works from bombing by our airmen was "comparatively insignificant," as also was the loss of life. There may, however, have been a considerable moral effect, involving a reduction in output, for we are told in the case of one large works that the German manager "was evidently very frightened, having constructed a bomb-proof portable cupboard for himself." The appearance of the manager in the role of a caddis-grub must have had a most encouraging effect upon his staff, although German ways are not our ways. Such damage as has been done is attributable almost entirely to the acts of the Germans themselves, and as one might expect, it is confined to the French and Belgian-owned works. Machinery was either taken away wholesale and installed in German works, or was smashed up beyond the possibility of repair. Some of the scrap so obtained was melted down for munitions, but it is clear that the main object aimed at was the prevention of future competition, because the most vital parts of the plants were systematically selected for destruction, even when there was ample material available in other parts of the works. The Sambre-et-Moselle works, perhaps the finest in Belgium, was left practically intact by the Germans, and the Commission were informed that the reason it was spared was because of the large interest in it, held by the German capitalist Thyssen. The Belgian-owned works in the same district were, on the other hand, completely destroyed, and will take several years to be reconstructed. At Pont à Verdun near Lens, a coal-mine producing 4,000,000 tons per annum, together with a modern coke-oven and by-product recovery plant, comprising some 580 regenerative ovens was completely destroyed by the Germans at the beginning of 1917. The pre-war cost of the mine and works was 200,000,000 francs, and it will be ten years before they can be restored to their former level of production. Of the 8,000 houses built by the company for its employees only 150 are capable of being restored. To read of such cases makes one realise the meaning of the word "reparation" to our Allies, and the justice of their insistence upon it. Photographs of engine-rooms and other parts of some of the fine Belgian works showing their state before and after the German "frightfulness" are given in the Report.

The rehabilitation of the iron and steel industry in Lorraine is hindered by an acute need of coke for the blast-furnaces. When the Armistice was signed, 60 out of the 68 blast-furnaces in Lorraine were found to be in good condition, but only five were in blast. The French got about a score in operation, but at the time of the visit of the Commission none of the blast-furnace plants were in anything like full operation. As the steel-works are dependent upon them, both these and the rolling-mills are all on short output. The Lorraine iron and steel works rely entirely upon Germany for fuel, and particularly for coal and coke from Westphalia, as the Saar coal, by itself, will not coke properly. Under the terms of the Armistice,

the Germans were to supply 13,700 tons of furnace coke per day, but only about one-third of this has been delivered, notwithstanding the fact that 800,000 tons of furnace coke were in stock in Westphalia. Efforts were made to get Belgian coke, but this would almost seem a policy of despair. The French are most anxious to terminate the present position of dependance upon Germany for coke supplies, as it places their iron-industry at the mercy of their enemies, and they hope for the conclusion of some arrangement whereby we may provide them with either coke or coking coal in return for basic pig-iron which we badly need. The withholding of the promised coke by the Germans has the appearance of deliberate policy. The Commission found that there was ample labour available, and if the fuel difficulty could be overcome there was nothing to prevent the Lorraine works giving a large output. The restoration of these areas to the French is considered to be advantageous to British industry on the whole. France is now in a position to produce 11,000,000 tons of pig-iron annually as against 5,000,000 before the war, the difference being at the expense of Germany. She may become a competitor to Great Britain so far as her surplus production is concerned, but not for some three to five years hence, when her full productivity can be realised. So far as ore is concerned, France has replaced Germany as the possessor of the largest reserves in Europe, totalling 5,500,000,000 tons, or four times those of Germany. An annual production of 21,000,000 tons has been transferred from German to French ownership, so that the French ore output now may be estimated as some 41,000,000 tons annually as against 8,000,000 tons for Germany. The latter country will, therefore, want ore from France, but she will not be so entirely dependent upon French ore as France will be upon German coke until some other coke supplies can be rendered available.

The practice with regard to blast-furnaces in Lorraine is to build them lower and with larger hearths than in England. A make of 200 tons per 24 hours is commonly obtained from a furnace 70 ft. high with a hearth 13 ft. to 14 ft. 6 in. diameter, and a blast-pressure of 6½ lbs. to 7½ lbs. per square inch. Less power is required than for the pressure of 10 lb. to 12 lb. common in this country. In only one instance was a combustion of more than 200 lb. of coke per square foot of hearth per hour noted. Dimensioned sketches of a number of typical furnaces are given and an interesting table, showing output, coke-consumption, &c., of various types has been prepared by Mr. R. C. Harding. In nearly all the works visited, the lay-out and equipment are said to be excellent. Electric cranes and labour-saving devices are used wherever possible. The steam-driven rolling-mills have three-crank compound reversing engines exhausting into a central condensing plant. Where open-hearth steel furnaces are installed they work with 75 per cent. to 80 per cent. of scrap and the balance of pig-iron. Moreover, they reckon to get three, four, or even five tappings per 24 hours, all of which conditions are said to compare favourably with English practice. The Commission was much impressed with the splendid stock-yards at most mills. It appears to be the common practice to carry very large stocks of all sections, cold straightened, and ready for immediate delivery. At Bombas works there were 27,000 tons in stock, and at Hayange the normal stock was 15,000 tons. The stock-yards are generally roofed over, equipped with labelled racks and stands, and provided with fast electric cranes.

Economy of fuel in the steel trade was found by both sections of the Commission to have been very carefully studied. All waste heat is utilised, and at every works the blast-furnace gas is carefully cleaned and fully absorbed. The Homecourt works, before the war, produced 9,000 tons of pig-iron and 7,000 tons of steel per week, yet they only used 40 tons of coal per day, the rest of the fuel being blast-furnace gas. This is said to be typical. The molten metal from the blast-furnaces is taken direct to the mixers in the adjacent steel-works. All blowing engines, and engines for power purposes are driven by furnace gas, and the exhaust gas from a 3,000 h.p. engine is capable of raising 2,400 lb. of steam per hour at 225 lb. per square inch and 100 deg. F. superheat in a waste-heat boiler. Nearly all the steam required was obtained in this way. The works are frequently able to sell the surplus power derived from their gas engines, for lighting and power purposes in the neighbourhood. The effect of this policy of utilising blast-furnace gas on the atmosphere of the thickly populated industrial areas of France and Belgium is said to be remarkable. Little, if any, smoke is emitted, and the contrast with conditions prevailing in similar localities in Great Britain is very striking.

The impression one gathers from the report is that all the works which have not been destroyed or dismantled by the Germans are thoroughly well-equipped for economical production, and in many cases are far more favourably circumstanced than our own for this purpose. Costs of production have, as in other parts of the world, risen enormously owing to higher wages and shorter hours of labour. A great deal of useful information is given on the subject of present-day costs as compared with pre-war conditions, but the report itself should be studied on the subject. The present cost of making basic pig-iron in Lorraine is stated to be about 200 francs per ton, of which 30 francs is the cost of ore, 105 francs that of coke, while labour and on-costs amount to 65 francs. In the Saar Valley the cost of production of basic pig-iron was said to be 305 marks per ton. The Lorraine miners earn from 25 francs to 30 francs per day, but are agitating for less hours and more money. Rolling-mill labour costs considerably less than in Great Britain, quite apart from the saving due to the improved mechanical equipment of the foreign mills. A head roller in a large section mill makes only from 15 francs to 20 francs per shift, and the average wages paid to other mill-hands are lower than here. Taking all things into consideration, the Commission express the opinion that the works visited in the Lorraine area can produce finished steel of ordinary quality at about 10s. to 15s. per ton less than the best equipped works in this country.

The conclusions arrived at by the members who visited the Cologne area are not much more reassuring. They find that no technical developments of importance, or large extensions of works had taken place during the war, and yet in spite of the extensions to British works during the same period, they consider that the German technical and mechanical attainments are still greater than our own. Thus, were competition to be resumed on a pre-war basis, we should not even now be able to compete effectively with German steel products. But fortunately for us, that basis can never be re-established. The Commission state that German labour has asserted itself to a degree unknown before, wages generally have greatly increased, and efficiency diminished. Germany is said to be suffering even more than England from labour unrest, high wages and shortage of food and material. Trade unionism has taken a strong hold, and the indications are that organised labour intends to retain the position gained. Wages were from two to three times as much as in the pre-war period, and labour difficulties were in evidence at every works visited in the Cologne area. Clerks, foremen and chemists were on strike, as their wages had not risen proportionally with those of the workmen, and pickets were on duty at the gates of the works. The eight-hour day was introduced on November 1, 1918, and engineering shops are working one shift only, namely from 7 a.m. to 4 p.m. In addition to the direct result of the increase of rates of wages and the reduction of hours, on the cost of production, the efficiency of the men was said to be only about half that of the pre-war period, and the managers of the works generally expressed despondency as to any considerable recovery in the future. It must be remembered, however, that the German works are intact and more advanced in their equipment and organisation than our own are, so that even if the temporary demoralisation of their workmen is greater than that of our own fellow-countrymen, their present difficulties afford small basis for hope as to our own future unless in the meantime we reach or exceed the high mechanical and technical efficiency which they have attained. Moreover, the comfortable housing provided for the men, the facilities for gardening and recreation, and the excellent washing and bathing accommodation furnished at the works should also be more characteristic of our own modern industrial undertakings.

In Luxemburg, which was nominally a neutral country during the war, the works were not destroyed. The German-owned works were practically shut down when the Armistice was declared, but those owned by French and Belgian capital present a cheerful air of activity, and have an output as great as the supply of coke permits. There is a ready market in Belgium for their products, and the men are putting their hearts into their work. In Belgium itself the outlook is anything but bright. The owners of the destroyed factories had nearly all made enquiries in England and elsewhere for plant and machinery, but the prices quoted both for machinery and structural steel were practically prohibitive of business. It seems impossible to realise the disastrous extent of the injury which the former great Belgian iron and steel industry has suffered at the hands of the Germans. Of 60 blast-furnaces in the country, not one was in operation at the time of the visit of the Commission. The unemployment is appalling, 800,000 men out of 1,200,000 are out of work according to the figures of the Minister of Economics at Brussels. Several years must elapse before the iron and steel trade in Belgium can be restored, and the destroyed factories rebuilt, and the work is being hindered by the excessive cost of materials even if they are obtainable. The Commission are of the opinion that a valuable market during the next two or three years would be secured for British iron, steel, machinery and plant in Belgium and France, if suitable financial arrangements can be made.

We have been unable to do more than summarise the principal conclusions of the Commissioners. The report itself is incapable of summarisation, for it contains hardly a superfluous word. It consists, excluding diagrams and maps, of some 75 pages of condensed technical facts and figures, compiled by just the kind of men who would understand what they saw and note the important points. Not only is it of the highest interest as a picture of the condition of the iron and steel works in the great industrial strip of Europe, and incidentally of the economic and psychological condition of the workers, but as a record of the equipment of many works which have long been famous for their steel products, it should be invaluable to the leaders of our own industry. One cannot feel any exhilaration over the considered statement of the Commissioners that in spite of our recent developments the German works are still superior in point of technique, mechanical equipment and labour-saving appliances, to say nothing of the provision for the health and comfort of the workers. Yet, if these things are so, it is well to know them. They must still remain controlling factors in efficient production, and in the future, as in the past the nation that neglects them will lose its place in the markets of the world. The three duties which the Report lays upon Great Britain are, firstly to provide coke for Lorraine, secondly to make arrangements for British material to be supplied to the devastated industrial areas of Belgium and France, and thirdly, but not least in importance, to put our own house in order.

SOUND PROPAGATION AND THE EFFICIENCY OF FOG SIGNALS.

WHILE the propagation of sound waves of small amplitudes, such as produced by ordinary acoustical instruments, has received much experimental study in laboratories and in closed halls, the propagation of sound waves of considerable amplitudes in the free atmosphere, disturbed by wind, rain, humicity, thermal currents and electric forces, still offers many perplexing problems. Fog signals, in particular, remain wasteful, inefficient and unreliable, and at present more attention is, indeed, paid to the development of submarine and radiotelegraphic signals than to the improvement of the fog-signal service. Applied acoustical science altogether is

somewhat backward compared to electric science, especially when we consider that the cultivation of music is as old as the human race, and applied electric science hardly older than the present generation. But acoustics seem to be rather the domain of the specialist, whilst electricity has become the science of the general practitioner, so to say. When physicists hit upon some promising electric novelty, it does not take the electrician long to adapt it to practical purposes; but the expert on acoustics may preach for a long time before the architectural builder and the engineer deem it worth their while to see how halls and rooms could acoustically be improved in accordance with scientific progress.

In our issue of July 20, 1917, we reviewed recent researches on the acoustic efficiency of fog signals in connection with the experiments conducted before the war at the fog-signal station at Father Point, near Rimouski, on the southern bank of the St. Lawrence—there already a bay more than 30 miles wide—by Dr. Louis Vessot King, of McGill College, Montreal. A fuller account of these experiments and their theoretical bearing was published in the *Philosophical Transactions* of April 23 last (vol. 218, pages 211 to 293), and Dr. King has also given a further account of the researches, which were resumed in the autumn of 1917, in the Transactions of the Royal Society of Canada, vol. 12, pages 109 to 113, March, 1919. Dr. King makes use of a thermodynamic method to determine the proportions of energy converted into air waves. His source of sound is the diaphone of J. P. Northey, a hollow cylindrical piston moved to and fro by the driving air so as to open and close circular slots in the piston communicating with similar slots in the inner cylinder. The diaphone gives, in a conical horn or trumpet, a note of about 180 vibrations per second. The other chief instrument is the phonometer of Professor A. G. Webster, of Clark University, Worcester, Mass. As used by King it may be described as a Helmholtz resonator and combined phonograph and mirror galvanometer, serving to measure the amplitudes of a mica diaphragm. We gave some particulars of these instruments in our previous article, and will now summarise the results obtained.

The acoustic efficiency of the diaphone measured in the contracted portion of the conical trumpet was about 5 per cent. (up to 8 per cent.) when the piston was worked at a pressure of about 25 lb. per square inch. The compression in an aerial sound wave, corresponding to the transmission of the observed amount of energy over the narrowest part of the trumpet, was as high as $\pm 0{\cdot}1$ atmosphere. This high figure clearly shows that the sound waves from sirens fall into the region of abnormal sound propagation, to which the ordinary inverse square law—which is never quite correct, since sound waves are not propagated through the air without loss of energy—does not apply. As the sound wave advances it changes its form more and more into a "bore," in which regions of high compression and rarefaction travel close together. Owing to adiabatic heating and cooling of the wave temperature equalisation by thermal conduction takes place, and the amplitude is varied until normal propagation is reached. In practice divergence in three dimensions would probably tend to minimise the effects just referred to, however, and to establish normal propagation. Measurements of the falling off of the sound intensity with increasing distance from the screen indicated that severe losses of energy occurred in the immediate neighbourhood of the siren; beyond distances of 1,000 ft. or 2,000 ft. the sound waves travelled without much energy loss on calm days. Sound intensity measurements carried out on 15 days, however, gave no general law as to the falling off of the energy, owing to the heterogeneity of the atmosphere. The square law was found utterly unreliable, even on comparatively calm days. The wind effect was by far the most important factor in the intensity fluctuations. Winds blowing against the sound propagation tend to refract the wave front upward, and lead to the formation of sound shadows on the surface of the sea. The acoustic survey supported the view of G. L. Taylor, that the high degree of sound attenuation in a wind may be ascribed to the eddy structure of the atmosphere, in accord with meteorological observations. The sound extinction from this cause seemed to be particularly severe within the radius of about half a mile from the siren, and eddy currents due to the buildings near the siren probably have a share in these disturbances.

In the observations of 1917, which are in accord with the conclusions previously arrived at, thermo-couples were inserted on the low-pressure and on the high-pressure side of the piston. Special meteorological observations were made with the aid of anemometers and other instruments by Mr. J. Patterson and Dr. A. Norman Shaw, and the quality of the sound was investigated, at various distances from the siren, by the aid of the phonodeik of Professor Dayton C. Miller, of Cleveland, Ohio. Professor Miller, who is a recognised authority on acoustics, described his share in these experiments in the same Transactions of the Royal Society of Canada, vol. xii, pages 161 to 169, September, 1918. In his phonodeik the vibrations of a diaphragm are mechanically transmitted to a small mirror, and direct photographic records of the sound waves are thus obtained. Miller took 23 such photographs at distances from the siren varying from 760 ft. to 13,000 ft., and he found that, especially close to the building, the sounds were very complex and variable, as they appear to the ear, owing probably to incidental conditions of the apparatus and of the atmosphere. Within 2 miles the loudness of notes of relatively low frequency was reduced to one-half; the higher notes were weakened to a much greater degree, and if the sound consisted only of the higher overtones nothing would probably travel beyond 2 miles. As a result the sounds increase in general in gravity with the distance. When Dr. King varied the siren pressure between 29 lb. and 6 lb. per square inch, the signal efficiency decreased from 24 per cent. at low pressure to 8 per cent. at high pressure. Thus, contrary to other suggestions, high-pressure sirens are not to be recommended, and it would appear advisable to separate big sirens into a number of small units. Further investigations are, of course, required. It would be a pity to supersede the siren fog signal stations by submarine and radiotelegraphic signals, which have their weak points as well. But we have much to learn yet as to the proper construction of fog-signal stations, and numerous stations might be erected at reduced expenditure.

THE BRITISH ASSOCIATION.

WITHOUT awaiting the formal inauguration of the proceedings by the delivery of the President's address, the twelve sections of the British Association at Bournemouth settled down to business by 10 o'clock last Tuesday morning. In accordance with the old-established practice the delivery of the President's address would have taken place on the eve of the sectional proceedings. Due notice of this change had been given, but it had apparently been overlooked by some of the old members. All the sectional presidents, however, faced crowded rooms when giving their addresses. Members are keen to discuss papers, and the 87th meeting of the Association altogether has opened most propitiously. It should have been the 89th meeting, since the British Association for the Advancement of Science was born at York in 1831.

Many familiar faces, young and old, will never be seen at the British Association again. Yet the Treasurer, Professor John Perry, was able to announce at the close of the ceremony on Tuesday evening, when the President's address was delivered, that 1,425 members had entered their names. The attendance exceeds expectations. A good meeting was counted upon, but it was hardly anticipated that Sir Charles A. Parsons would preside over a big meeting in the "bright, bracing, beautiful Borough of Bournemouth," to use the words of Sir Oliver Lodge, when seconding the vote of thanks to the President. The vote of thanks was proposed by the Mayor of Bournemouth, Alderman E. E. Bishop, and Sir Oliver Lodge's remark was made in response to the welcome that the Mayor had offered to the Association; the President's turn to thank the hosts will come with the concluding meeting.

Three years having elapsed since the last Newcastle meeting of 1916, both the Presidents, Sir Arthur Evans and the President-Elect, the Hon. Sir Charles A. Parsons, K.C.B., M.A., D.Sc., F.R.S., had occupied their distinguished offices for three years. There were other exceptional fixtures at the opening ceremony. In resigning his chair, Sir Arthur Evans first read a loyal message which the Counsel had submitted to the King on behalf of the Association. He then had to refer to the loss the Association had sustained in the interval by the deaths of four renowned scientists, eminently connected with the Association, two past presidents, Sir William Crookes and Lord Rayleigh, a general treasurer. Professor G. Carey Foster, and a general secretary, Professor A. Vernon Harcourt. All these which have been recorded in our columns, fall in the present year. Sir Charles Parsons had selected "Engineering and the War" as the subject for his address, but he added some highly suggestive suggestions for the future to the numerous interesting facts and figures which he put before his audience. As we print his address in another part of the present issue, we will not deal with it further here. Fortunately there have been no changes in the chief officers of the Association. Professor John Perry, F.R.S., remains treasurer, and Professor W.A. Herdman, F.R.S., and Professor H. H. Turner, F.R.S., remain General Secretaries; but Professor Herdman is resigning next year to preside over the Association meeting at Cardiff. The Assistant Secretary, Mr. O. J. R. Howarth, and the chief clerk and assistant treasurer, Mr. H. C. Stewardson, also retain their offices.

Associated as Vice-Presidents with the Mayor of the town, which had extended the invitation, the County Borough of Bournemouth, were this time the Mayors of two other towns, Christchurch and Poole. The visitor riding on the top of a tramcar eastward from the Square, Bournemouth, hardly notices that he is passing into Boscombe, Pokesdown and Christchurch, or that he is leaving Hampshire and entering into Dorsetshire when proceeding westward through West Bournemouth to Poole. It is a very pleasant ride all through, and a good portion of the route seems to lie through bush and gardens studded with houses rather than along streets. Up till 1856 the affairs of Bournemouth were administered from Christchurch, and the charter of the incorporation of the County Borough of Bournemouth only dates from 1900. We dwelt on the modern character of Bournemouth in our preliminary article on the meeting published a fortnight ago. "Bournemouth is a town unhampered by a past," Mr. S. McCalmont Hill, then Mayor of Bournemouth, says in the foreword to the "Natural History of Bournemouth and District," which was compiled in 1914 by members of the Bournemouth Natural Science Society, and edited by Sir Daniel Morris, who is president of Section K, Botany, at the present meeting. The close association of Bournemouth with its neighbouring townships is not confined to the tramways link. The first Bournemouth gas-works of 1863 were in the Bourne valley. Later the Poole gas-works were taken over by Bournemouth, and new gas-works were erected there; Section G paid a visit to the gas and water-works during the meeting. The company is so constituted as to make the interests of the public, the employees and the shareholders identical. For every penny per 1,000 cub. ft. of gas, by which the price of gas is reduced below a fixed standard, the company can pay to its shareholders ¼ per cent. extra dividend on their extra capital, and an additional bonus of 1 per cent. upon their wages to its employees under the co-partnership scheme. In these words Colonel H. W. Woodall, M.Inst.C.E., general manager of the gas and water-works, explained the financial arrangements adopted in the "Natural History" to which we have referred. When in 1886 the water from the Bourne rivulet was no longer sufficient for the town supply, pumping and filtering stations were erected at Longham and Alderney, some six miles from the town. Within less than ten years an extension became necessary, and a well 10 ft. diameter, 212 ft. deep, was sunk at Walford Bridge, near Wimborne, in Dorsetshire; the hard water from this well is softened on the

Haines system by mixing it with a stream of milk of lime in a covered reservoir. The electricity supply was first also from works on the Bourne. The present supply area comprises the townships we mentioned, and extends at Christchurch beyond the 12 miles' length of the tramway, the total length of its area being 14 miles. At the principal generating station of the Bournemouth and Poole Electricity Supply Company vertical engines of 8,000 h.p. drive single-phase generators yielding current at 2,250 volts and 100 periods for the general supply and further continuous current-dynamos for currents of 565 volts for traction and power purposes; the new plant installed consists of high-pressure steam turbines driving combined single and three-phase generators.

The Municipal College, which also may be said to serve the whole district, was only opened in 1913. The College prepares for the Universities. In the year 1914 the number of students had reached 1,200, and it is coming up to that figure again now. The College certainly offers the best accommodation for the sections and committee rooms and the association in general which members have enjoyed of late years. The reception room and the working and general rooms are most convenient, and the centralisation of all the offices and meeting places is a fixture of considerable importance. The evening discourses are given in the pavilion of the Winter Gardens, when the opening meeting was held on Tuesday evening. We commence our report of the sectional meetings by dealing with Section G, Engineering.

SECTION G.—ENGINEERING.

THE meetings of the Engineering Section were held in the Engineering Annexe of the Municipal College. The proceedings of Tuesday, the 9th inst., began at 11 a.m., when Professor J. E. Petavel read his Presidential Address. There was naturally no discussion in connection with it, and, as we print the address in full on pages 350 and 351 of the present issue, it is not necessary for us to deal with it further in this place.

STRESS DISTRIBUTION.

The remainder of the first morning's sitting was spent in the reading and discussion of the Report of the Committee on Stress Distribution in Engineering Materials. There was but a small attendance to hear this report and the discussion was of a very slight nature. Professor E. G. Coker, who was secretary to the Committee, read the report. The name of Professor Petavel, the President of the Section, appeared in the Report as a joint secretary with Professor Coker, but at the beginning of the proceedings Professor Petavel announced that Professor Coker had done all the work. The Report was of a nature difficult to summarise, but it will not be necessary for us to say very much about it here, as we propose to print it in full in a later issue. It consisted of six independent contributions as follows: "The Strength of Tubular Struts," by Major Andrew Robertson; "Investigations of Stresses in Aeroplane Wing Frameworks," by Professor L. N. G. Filon; "The Soap Film Method of Stress Estimation," by Mr. A. A. Griffiths; "Eccentric Loading in Tension and Compression Tests," by Mr. W. A. Scoble; "Experiments on the Effect of Alternations of Tensile Stress at Low Frequencies on the Elastic Properties of Mild Steel," by Major A. R. Fulton; and "The Strain-energy Function and the Elastic-limit," by Mr. B. P. Haigh. The last contribution was read by its author, but the whole of the remainder were dealt with by Professor Coker, as none of the other contributors were present.

As the main part of what small discussion there was turned on Mr. Haigh's section of the Report, we may say that it represented a tentative consideration of the problem of elastic-limits under simple and complex stresses by considering the matter from the point of view of the *energy* absorbed by the material in virtue of its elastic strain. The method was necessarily based on thermo-dynamic considerations, but the paper was confined to the examination from this point of view of experimental results already published. The mechanical energy absorbed by a body stressed within the elastic-range was variously termed the "strain-energy" or "resilience." The term "limiting strain-energy" was used in the paper to signify the quantity of energy which could be absorbed per unit volume of material uniformly strained to its elastic limit by the application of specified combinations of principal stresses. The immediate object of the investigation was to find how nearly constant was this quantity, for any one material, independently of the nature of the simple or complex stress applied. The examination of a number of results of various investigators, already published, showed a very fair approximation of the experimental results with what was obtained from the strain-energy consideration.

Sir J. A. Ewing opened the discussion. He said the Report was a good example of the valuable type of work which was carried out by the British Association. The Reports on gaseous explosions, which he had recently been studying, were further examples. This particular class of continued research was, he thought, carried out by no other body. He had not seen the Report before he entered the room, which was an example of the way people could be credited with work they had not done, since his name appeared as a member of the Committee. The Report was too extensive for him to enter on without careful study, but he would like to refer to Mr. Haigh's contribution. The suggestion that the transformation of a body between the crystalline and the non-crystalline states could be treated thermo-dynamically was interesting. But on this basis the change would, of course, have to be reversible, and he had a good deal of difficulty in accepting that. He thought it much more likely that the change was irreversible, like the case of a super-cooled vapour deposited on neuculii. That is, the change would be from a stable to a meta-stable state and, therefore, irreversible.

Mr. C. E. Stromeyer, referring also to Mr. Haigh's contribution, said that some years ago he had drawn a number of curves corresponding with those in which Mr. Haigh compared experimental results with his energy theory, but had obtained curves of a very different shape from those given in the report. On the whole, however, he thought it was not worth while hunting for mathematical formulæ which would foretell the results of experiment. We should plot what results we actually obtained, and not jump to theoretical conclusions. To theorise about combined stress at the present time was to go off on the wrong tack.

Mr. J. S. Wilson, referring to the contribution dealing with aeroplane wing framework, asked what happened at a joint. The stress in the actual material had been investigated, but the question of the stress at a joint was not gone into.

The President (Professor Petavel) congratulated Professor Coker on the Report, which, as he had said, he personally had had nothing to do with. It was very valuable. In many branches of work advance had now reached the point at which it was necessary to know fairly exactly what went on in a material of construction. Aeroplane construction was an example of such a branch of work, in which factors of safety were low. Research such as that of the Report would undoubtedly, bit by bit, build up a structure of useful and directly practical knowledge.

Professor Coker, in reply, said that the only reason he had prepared the Report was that Professor Petavel and he had agreed to divide up the work, and this year it happened to be his business to get the Report together. He had found each contributor very ready with his particular part of the work. In connection with Mr. Wilson's question about joints, he would say that the question of the stresses at a node had not been overlooked. It had been very seriously considered, but the determination proved one of great difficulty. Further work was in progress.

Mr. Haigh also replied to the discussion. He said he had not time to enter into an examination of the point raised by Sir J. A. Ewing. The paper pretended to be only a record of experiments, but he firmly believed that the change of the state of the material could, under certain conditions, be reversible.

The proceedings of Wednesday, the 10th inst., began at 10 a.m., when the President of the Section, Professor Petavel was in the Chair. Three papers were read during the morning, the first being that by Sir Eustace d'Eyncourt entitled "Account of the British Tanks used in the War," and of which we begin publication in full in the present issue. There was a large attendance for the reading of this paper, but the audience was in great part a non-technical one, and the paper was not the subject of any extensive discussion. The other two papers dealt with were that by Professor Inglis on "Portable Military Bridges," and that by Mr. R. J. Walker on the "Development of Geared Turbines for the Propulsion of Ships." We propose to publish both these papers in a later issue, and will next week deal with the discussion on them and on Sir Eustace d'Eyncourt's paper.

In concluding our notice for this week we should say that on Tuesday, the 9th inst., the engineering section, in the afternoon, paid a visit to the tramway generating station of the Bournemouth Corporation where demonstrations were given of electric welding, oxy-acetylene welding and cutting, and the sorbitic treatment of rails *in situ*. On the afternoon of the 10th inst. a visit was paid to the Christchurch R.E. Training Camp to witness a demonstration of bridge construction of the type dealt with in Professor Inglis's paper.

NOTES.

LEAD-NITRATE HYPOPHOSPHITE DETONATORS.

THOUGH phosphorus has been utilised in various ways in warfare, attempts to use phosphorus and its compounds in the manufacture of explosives have been little successful. The *Chemische Zentralblatt*, the old-established German abstract journal for theoretical and technical chemistry, recently noticed a paper contributed by Edmund von Herz to the *Zeitschrift für das Gesamte Spring-stoffwesen* in 1916. By mixing lead nitrate and lead hypophosphite Herz obtained a highly-explosive complex lead salt, a nitrate and hypophosphite. To prepare this compound a hot saturated solution of lead nitrate containing 331 grams of this salt is added to a boiling saturated solution of calcium hypophosphite (170 grams); the mixture is rapidly cooled while being vigorously stirred; white crystals, of a greasy lustre, of lead hypophosphite are then obtained. These cryst ls are redissolved and 250 grammes of the solution are mixed with a boiling solution of 500 grammes of lead nitrate in 1·5 litre of water; again the mixture is rapidly cooled. When the preparation is successful the double salt $Pb(NO_3)_2$ $Pb(H_2PO_2)_2$ is obtained as a granular crystalline powder which is dried at a temperature of 40 deg C. or 50 deg. C.; when the salt separates in needles or as a felted voluminous mass, it is less suitable as a detonator. As regards the rate of detonation the proper lead nitrate-hypophosphite comes up to lead azide and surpasses mercury fulminate. Its decomposition liberates a comparatively small volume of gas, 117 litres per kilogram, whilst lead azide yields 230 litres and mercury fulminate 314 litres of gas; the new compound is therefore not a very efficient primary explosive. But it offers considerable advantages as a material for percussion fuses, being both sensitive and stable and yielding a flame of high temperature. The lead nitrate acts as oxygen carrier in this compound.

HYDROGEN-OCCLUSION BY METALS AND MAGNETIC PROPERTIES.

The combinations between metals and hydrogen differ much in type. In the *Journal of Physical Chemistry*, vol. xxiii, pages 186–202, 1919, Donald P. Smith distinguishes three types of such compounds. The compounds of the first type like H_3Sb are non-metallic in character, gaseous at ordinary temperature, and the hydrogen in them appears to constitute the electropositive element. Such compounds are only formed by elements like bismuth and arsenic, which resemble both metals and metalloids, as well as by decided metalloids like phosphorus; in other respects they are analogous to the hydrocarbons. The second class, the hydrides proper, compounds between the metals of the alkalis

and alkaline earths, KH, Ca H_2, &c., are likewise non-metallic. They form colourless crystals;* some of them can be volatilised without decomposition in an atmosphere of hydrogen, and they may be regarded as salts in which the hydrogen forms the electro-negative element. The third-class of compounds, of which palladium-hydrogen is the best known representative, are not compounds, but rather solid phases of the character of alloys, the compositions of which vary with external conditions. They are not volatile as such; the hydrogen is expelled from them by heat, and is said to be held in solution by occlusion. Many of the heavy metals occlude hydrogen; chromium only does so apparently when electrolytically deposited, when it may occlude 250 times its own volume of hydrogen. Manganese is considered doubtful, though it is believed to increase the capacity of iron for adsorbing hydrogen. On the other hand, tungsten, molybdenum, rhodium, silver, gold, zinc, cadmium, tin, mercury, lead and bismuth are not considered to occlude hydrogen. Some of the rare earth's metals, like cerium and lanthanum, form exothermic compounds with hydrogen, under great evolution of heat, whilst the occlusion is generally endothermic, and the reaction very feeble. A good many cases remain doubtful, because we really do not know whether the metal from which we start is pure and free from hydrogen. Donald Smith now points out that the peculiarities of the three types he distinguishes, and of the allocation of the various metals to them become less striking when the elements are grouped according to Werner's arrangement of the periodic system. In Werner's periodic table the occluding metals occupy distinct regions, and Smith draws particular attention to the connection between the magnetic properties of the metals and their occluding power for hydrogen. Metals possessing a magnetic susceptibility greater than $+ 0{\cdot}9 \times 10^{-6}$ (at ordinary temperature) have a high occluding power, and on the other hand low magnetic susceptibility goes together with low occluding power. In fact, the curves of these two properties coincide more closely than curves of cognate properties generally do. But there are exceptions, especially thorium—about which there is doubt, since pure metallic thorium is hardly known—rhodium and copper. Rhodium has a high magnetic susceptibility, but does not occlude hydrogen; whilst copper does occlude, but is not ferromagnetic, being under ordinary conditions, feebly diamagnetic, in fact. Yet, according to Wedekind, copper must be regarded as "latently" ferromagnetic, from the behaviour of some of its compounds, and there certainly seems to be some ground for assuming a parallelity between the magnetic properties and the occluding power for hydrogen. The further problem is the investigation of the possible cause of this particular interrelation.

INDUSTRIAL NOTES.

IT is reported that a most important transaction, which has been pending for several months past and has been known as "The South Wales Trade Deal," has now been completed. It is stated that Mr. H. Seymour Berry, Merthyr Tydfil, in conjunction with Mr. D. R. Llewellyn and Lady Rhondda, has acquired the control of the firm of Messrs. John Lysaght, Limited, the well-known iron and steel manufacturers. The deal, it is added, involves a total sum of close upon 5,000,000*l.*, and also establishments outside the South Wales area, and in Australia. Shipping interests are represented by subsidiary companies working between Great Britain and Australia. The new directorate is to include Messrs. W. R. Lysaght, S. R. Lysaght, D. C. Lysaght and Mr. H. G. Hill, who are on the Board of Messrs. John Lysaght, Limited. Under the new control, Mr. H. Seymour Berry will be the chairman of the company, Mr. D. R. Llewellyn being the deputy-chairman. The Board is also to include Lady Rhondda, Mr. W. E. Berry and Mr. W. Trimmer.

The Municipal Tramways Association, embracing every undertaking of local authorities in the country, met in London, on the 4th inst., and passed the following resolutions unanimously:—

"That in view of the present financial position of the tramway undertakings, no further increase of wages can be granted without either: (*a*) Raising the fares, or (*b*) increasing local rates to meet deficiencies.

"That the circumstances of different parts of the country vary greatly, and therefore it is impossible to deal with the whole matter in one arbitration.

"If arbitration is adopted, it must be in districts throughout the country in accordance with the Wages Regulation Act.

"That in view of these facts we are prepared to accept arbitration from the Minister of Labour under the Wages (Temporary Regulations) Act, 1918, and the Extension Act of 1919."

Meetings subsequently took place at the Ministry of Labour, when it was decided to refer the matter to the Interim Court of Arbitration under the Wages (Temporary Regulations) Acts. A preliminary hearing will be given by the court early next week.

A private conference of the Triple Alliance (miners, railwaymen and transport workers) was also held in London on the 4th inst., in the matter of the ballot vote on "direct action." At the close, it was announced that the following resolution had been passed:—

"That this conference accepts the decision of the three Executive Committees of the Triple Industrial Alliance to adjourn the ballot vote, and the ballot hereby stands adjourned, and the whole question is adjourned until after the Trade Union Congress."

Speaking on this question on the same day at the Browning Hall, Walworth, Mr. Arthur Henderson said he had learned with considerable satisfaction that the Triple Alliance had decided with striking unanimity against a policy of direct action for purely political purposes. This was a wise and a commendable decision. He had used the terms "for purely political purposes," because he did not admit that the organised workers could entirely forego the weapon of direct action. When Labour had conquered political power, and had taken hold of the machinery of government, as they might presently be called upon to do, would they be prepared, he asked, to allow a minority, in opposition to their programme of social and economic betterment, to defeat that programme by unconstitutional methods. Rather should they set their faces firmly against any attempt to substitute such a method for the orderly peaceful procedure of the Parliamentary constitution.

Speaking at Carlisle last Saturday, and alluding to the Trades Union Congress which was to commence its sittings in Glasgow on the following Monday, the 8th inst., Mr. J. R. Clynes, M.P., said: ". . . Those of us who urge the workers to turn their minds to improved systems of production in order to increase output do so primarily in the interests of the workers themselves. Greater yield of commodities is essential in order that an abundance of products should bring down prices and place upon the market all the things which are necessary for improved housing, cheaper food and clothing, of which the workers are in urgent need. There can, however, be no greater output without the assurance to the workers of greater comfort for them in our social and industrial system, and a higher standard of living than they had before the war. They helped as much as any class to save their country by offering their lives for it, and they have as much right as any class now to enjoy a first and a fair share of the wealth produced by their labour. That share they could get by intelligent and temperate action at the polls, but not by the ruinous use of stoppages or strikes for political objects."

One of the most important features of the measures for resettling ex-service men in civil life is the Government scheme whereby ex-officers and other ranks of good education may be assisted to take up or resume training for business and professional careers. In the phase of the work dealt with by the Appointments Department of the Ministry of Labour, training is arranged for in offices and works, &c., and the co-operation of employers is therefore essential to success. Many employers have responded with the greatest willingness to the appeal which has been made to them, and although the scheme has only been working fully for a comparatively short time, over 3,500 students are now in training. Engineering is a profession which is greatly sought by candidates, and on August 22 there were 602 students training in the various branches of the profession. The number of applicants is, however, very greatly in excess of the number of training vacancies available, and employers who can help by offering to train suitable candidates are urgently requested to communicate with the nearest district office of the Appointments Department.

The Trades Union Congress commenced its sittings in Glasgow, as stated, last Monday, and Mr. G. H. Stuart-Bunning, the president, in the course of his opening address, stated that the figures of affiliated membership for this year showed a record total of 5,265,426. After speaking against direct action, he dealt with the question of increased output and stated that the world was five years behind time; the wastage had to be made good, the lost time made up and there should be, in consequence, an increase of productivity. But the result aimed at would not be obtained by calling the labour men "slackers." For one thing they were not slackers, and if they were, that would not be the way to improve matters. It was not surprising that after five years of persistent effort, of long hours, and sometimes insufficient and unpalatable food, some weariness should be noticeable. It was not strange that men who had been fighting for years in the most awful conditions should require some little time to get back their old skill and aptitude. It should be clearly understood that increased output can only be obtained by the co-operation of both employers and employed, and the employed are willing to do their share.

In the nationalisation of mines, the miners had been fighting for an item which had been on the labour programme for many years, and he knew he voiced the feeling of Congress when he thanked the miners for their fight, and assured them that the Congress was not weakening on the subject of nationalisation.

In concluding, Mr. Stuart-Bunning stated, "the great war is over; let us not seek to carry it on either in this Congress or elsewhere. There is so much to do that there is no time to waste in hatred; hate destroys, and it is our function to construct. Let us, therefore, so construct that we leave behind us a lasting foundation for peace, and a beautified and happy country."

At Monday's meeting Mr. J. Bromley (Leeds, Locomotive Engineers and Firemen) moved that the Congress instructs the Parliamentary Committee to draft a practical and effective policy for the control of industry, whereby the trade union movement can secure for democracy complete emancipation from wage slavery. The workers, he said, should have the fullest right of saying how their industry should be run and managed in the interest of the whole community. They believed that co-partnership and profit-sharing schemes were only capitalistic dodges to prevent the workers having control of the industries in which they were employed. The resolution was carried with one dissentient.

Mr. W. Scoggins (London, Compositors) moved a resolution in favour of free trade and against any system of preferential duties; free trade between the nations was the broadest and surest foundation for world prosperity; he asked that the Parliamentary Committee be instructed to interview the Prime Minister to obtain from him a clear statement of the Government's fiscal policy. Mr. Shaw, M.P. (Weavers), seconded.

Mr. J. Stokes (London, Glassblowers), speaking against the resolution, said that some articles of food and raw material were taxed, while manufactured goods were admitted free, with the result of killing certain industries. He moved that Congress proceed to the next business. This was defeated, and the resolution passed by a large majority.

At the sitting of the Congress on Tuesday, the 9th inst., Mr. J. T. Brownlie, chairman of the Executive of the Amalgamated Society of Engineers, called upon to speak with reference to his letter to Mr. Bowerman, on the subject of increased production (see page 273 *ante*), said the letter was written on his own responsibility and did not involve his colleagues. If he wanted any justification for it, it could be found in an agreement for a reduction of hours submitted to the trade unions concerned and stating: "The unions will take all possible steps to insure that in the critical stage through which the country is to pass the greatest possible output is secured and maintained." That agreement, he added, when put before the trade unionists in the engineering and shipbuilding industry received over 300,000 votes, and every man who voted in favour of the agreement and who participates in the 47-hour week is in honour bound to give effect to it. Some of his friends had interpreted his letter as a charge against the workers of being slackers; he repudiated that charge. So far as he was aware, no executive council of any trade union had encouraged what was known as the ca' canny policy. If there were men in the country who pursued this policy under their own leadership, they were pursuing a mistaken course. The function of the employers was to maintain production. On the other hand, the workers were not free from responsibility. He held that it was necessary now for the Government to organise the man-power of the nation for producing the necessaries of life. There was a power of production in this country which if properly organised and utilised would create a great abundance; but it was not properly organised. It was the duty of

* We might remark that different experimenters differ considerably as to the properties and formation of the hydrides.

responsible trade unionists to bring pressure to bear on the proper authorities to organise so that production can be increased and employment found for every man, woman and child in need of it.

Mr. J. E. Mills, A.S.E., who followed, said the truth was that the Government were to blame for any want of production. He was, he added, the secretary of the largest shop stewards' committee in Great Britain (the Woolwich Arsenal Shop Stewards) and could say that as the result of continual pressure on the Government by that committee, with the help of the chairman of the Parliamentary Labour Party, Woolwich Arsenal was turning out milk churns, and had orders for railway wagons and locomotives to keep the workers employed.

Mr. J. Havelock Wilson (Seamen), after referring to the fall in the American rate of exchange, stated that the 40,000,000,000*l.* spent by the nations in the war had to be made good, and it would only be made good by more production and harder work. Shortening of the hours of labour was a good policy, but if it did not provide the necessaries of life he knew who would be the first to complain. It was not always the man working at the bench who did the greatest amount of work and the most useful work. Some men must work with their brains, and very often brain work was more fatiguing than manual labour. It was courageous for a man like Brownlie to write the letter he did, and to incur repudiation by some of his colleagues, but he would say to him, "never mind, you are on solid earth, and the time will come when your attitude will be justified."

Then followed speeches by Mr. R. Smillie (Miners) and Mr. R. Williams (Transport Workers), who respectively moved and seconded a motion to refer back to the Parliamentary Committee a paragraph on direct action contained in the committee's report. Their desire was not so much to commit the Congress to the policy of direct action, as to censure the committee for declining to call a special congress in order to decide what action, if any, should be taken. The figures of the vote were :—

For reference back	2,586,000
Against	1,876,000
Majority for	710,000

They show that 4,462,000 votes were given, as against the record total of 5,265,426 affiliated members referred to above.

ENGINEERING SECTION OF THE BRITISH ASSOCIATION.

Address by Professor J. E. PETAVEL, D.Sc., F.R.S., President of the Section.

DURING the last five years every resource of the Empire—moral, intellectual and material—has been concentrated on one great task, now successfully achieved; and the present period marks the end of a gigantic military struggle and the beginning of a new social era.

I.—ENGINEERING AND SCIENCE DURING THE WAR.

To summarise adequately the part played by engineering in the war would constitute a task far beyond the power of the writer or the scope of the present address. Now, as in the past, the fate of nations in war or peace is primarily determined by moral, intellectual and physical attributes; but, under modern conditions, these forces can find efficient application, only through the agency of science and engineering.

A large army depends for its subsistence and equipment on the combined effort of every branch of human activity; and every productive industry, when organised on a large scale, is in turn dependent upon the engineer.

Before the end of the war this country had become transformed into one vast factory, every department of which required the services of trained engineers. Every member of this section has contributed his own share to the task, and our programme includes papers giving detailed accounts of several branches of the work. It is fitting, therefore, that I should restrict myself to a mere outline of some of the more outstanding facts :—

The urgent necessity for an output of munitions vastly in excess of any previous production made centralisation and standardisation essential, and involved a complete revolution in workshop practice. The Ministry of Munitions was responsible for the formation of the required organisations, and guided the transformation of industrial conditions, and, when the dilution of skilled labour become inevitable, the technical engineer designed the machinery and devised the methods which made efficient work possible. Credit is due to the unions for the concessions made; greater credit to the women for their enthusiastic response to the call and the steady output they maintained.

Munitions.—The Ministry of Munitions was created in May, 1915, its early efforts being concentrated on the production of guns and shells. A year later the Ministry was in a position to meet the ever-increasing demands of the Army, and by 1918 a large reserve of munitions had been established, the expenditure being limited only by difficulties of transport at the front. The maximum expenditure of ammunition was reached one day in October of that year, when 900,000 shells, weighing 40,000 tons, were fired. The total number of guns manufactured during the war was 20,000, and over 200,000 machine guns had been delivered by November, 1918.

The Ministry of Munitions took charge also of the production of aircraft, which were ultimately turned out at the rate of 4,000 per month; later the provision of motor transport was in addition placed under its control. Finally, our production of "poison gas," for which this Ministry was responsible, rose during the last few months of the war to several thousand tons a month, sufficient to make the Germans rue the day on which they had introduced this weapon into warfare.

Among the inventions which have had an influence on military operations I will mention only three as typical of three distinct classes :—

Tanks were first used in 1916, and the results produced were greatly enhanced by the surprise created, and consequent moral effect, but the idea of an armoured chariot is as old as organised warfare. The problem of constructing a vehicle which could travel across the trackless and shell-pitted district which extended between the two armies remained to be solved. In the light of the experience gained with various types of tractors it was, however, clearly not insoluble, and credit is due to the man who had the courage to hazard a novel and important experiment. The resulting tank was the product of careful design and experiment, and the outcome of the co-operation of several engineers with special knowledge. Sound-ranging introduced the complex methods and delicate instruments of physical research into the trenches, and, against all precedents, proved them to be reliable and practical under the most adverse conditions. The Stokes gun, on the other hand, superseded all other trench mortars by simplicity of design of manufacture and convenience in handling; 20,000 of these guns were used during the war.

Transport.—On August 4, 1914, the Government assumed control of the railway systems in this country, but the working and management was left in the hands of the railway officials, and to them is due the smooth working of the lines during a long period of exceptional difficulty. British engineers, civil and military, have been responsible for the transport through France, and during the last two years of the war large numbers of engines were sent across the Channel and miles of track was taken up in England and relaid in France. Road transport was organised on an unprecedented scale, and 100,000 new vehicles were delivered. A network of narrow-gauge railways was carried right up to the trenches, and numerous new roads, railway lines, and bridges constructed. Railway construction formed an important factor in connection with the advances in Mesopotamia and Palestine; in the latter case the entire water supply had for a long period to be drawn from the Egyptian base through a specially laid pipe line.

In France and elsewhere the armies were primarily dependent upon sea transport for their food and equipment. This service, organised by the Navy, culminated in the unique effort which brought American troops at the rate of 300,000 per month, and thus overbore the balance which for four years had been oscillating between defeat and victory.

Among the notable new departures the cross-Channel train ferry and the portable steel bridges, principally of the Inglis type, should be specially mentioned.

Navy.—At the outbreak of war the Navy was ill-prepared with regard to anti-submarine defence and mining. The influence of the submarine on naval warfare had been under-estimated, and mines were regarded as a somewhat discreditable means of destruction; but during 1915 the depth-charge and the Paravane were developed by the naval experimental department at Portsmouth, and later thousands of these were brought into use. In principle the depth charge consists of a canister containing a large charge of explosive and a pistol actuated by an hydrostatic valve. The merit of the invention resides in the simplicity, safety and reliability of the mechanism. In designing the Paravane the body was borrowed from a torpedo, and wings, rudder and elevator from an aeroplane. The secret of the device lies in the stabilising mechanism, which enables it to keep its position when the ship is running at high speeds. The Paravane enabled most ships to pass unscathed through a minefield, and in a slightly modified form it served to seek out and destroy submarines under the water.

Sound location proved to be one of the most valuable inventions developed by the Board of Invention and Research. By its means the position of a submarine explosion off the coast of Belgium could be found within a few hundred yards by observers on the English coast; passing ships or submarines could also be identified and located. Sound locators were also used on board anti-submarine craft, but at the time of the armistice were for this purpose being superseded by other methods.

Mine construction, laying and sweeping formed the object of many successive improvements. Mines of special construction, which cannot be swept by ordinary means and which explode without actual contact, were used in large numbers in 1918, and were particularly effective against submarines. Various new types of oscillating mines were also developed.

Many of the newer fighting units of the Navy were designed for speeds far in excess of anything that had been previously contemplated; the attainment of the required horse-power was rendered possible by improvements in boiler construction, by the development of oil-firing, and by the invention of the geared turbine. At the present time the horse-power of some of the fastest destroyers equals that of any pre-war Dreadnoughts.

Numbers of strange craft were designed for special purposes. The monitor was used as a floating fortress, and ships without funnels or masts formed cruising aerodromes. The torpedo net was known to be ineffective as well as inconvenient, but some years elapsed before ships were rendered immune to torpedo attacks by a wide outer sheaf of resilient construction. Some protection was first given to mine-sweepers by fitting the vessels with a false prow; the newer mine-sweepers were rendered nearly unsinkable by the provision of numerous bulkheads. The submarine was developed with regard to size, range and speed. The latest and perhaps the strangest craft was the submarine fitted with a heavy calibre gun which could be fired when all but the muzzle was submerged.

Aircraft.—The rapid progress and expansion of aeronautical science and construction is perhaps the most remarkable achievement of engineering during the war.

In 1909 Blériot flew the Channel. In 1910 Cody won the British Michelin Cup by a flight of 185 miles. The Royal Flying Corps was formed in 1912, and it was decided that the equipment should consist of 72 aeroplanes and 2 airships. The number of aeroplanes available in 1914 was under 200; the number ultimately required proved to be more than 3,000 per month. The aeroplanes which were sent out with the Expeditionary Force in 1914 had a maximum speed of some 80 m.p.h., a rate of climb at ground level of 300 ft. or 400 ft. per minute; they were equipped with engines of 60 h.p. to 100 h.p. In 1918 the fast machine had a maximum speed of 140 m.p.h., a rate of climb at ground level of 2,000 ft. per minute; single-seaters were fitted with engines of 200 h.p. to 300 h.p., and the largest machines were equipped with a power plant developing over 1,300 h.p. The maximum height attainable had increased from 5,000 ft. to 25,000 ft.

The Atlantic flight has given the measure of the success achieved in the design of long-range bombing machines. Two types were evolved: The fast day bomber, capable of carrying a useful load of about 3,000 lb., at a speed of 130 miles an hour, and the night bomber with a larger load and slower speed. The largest aeroplane manufactured in numbers was the Handley Page V/1,500, with a weight of 11 tons and a power plant of 1,300 h.p. Three days before the armistice two of these machines stood fully equipped waiting for the order to start for Berlin. The largest bombs in use weighed over a ton, and during the war 8,000 tons of explosives were dropped on the enemy. The experience which they had gained in the construction of the high-powered engines required for airship work proved to be a valuable asset for the Germans. Initially also their rate of production, both of aeroplanes and engines, was far superior to ours, and, faced with the menace of otherwise being for a period deprived of machines, we were bound to continue the use of certain standardised types longer than was desirable.

The labour difficulty was overcome by the introduction of a large proportion of female labour, which proved to be very suitable for aeroplane manufacture, and especially for wing construction. The bulk production of aero-engines presented grave difficulties. Every part had to be made to close limits so as to be interchangeable, and it was necessary to maintain the highest quality with the minimum amount of skilled labour. For a period the supply of magnetos was both inadequate and unsatisfactory. The Germans had acquired practically a monopoly in this direction, and it became essential for us to build up a new industry on the results of careful research and experiment. The fact that under these circumstances a total of 8,000,000 h.p. was produced during the last twelve months of the war represents one of the greatest achievements of engineering organisation.

Synchronised gun firing through the propeller was first brought into use by the enemy, and the success of the Fokker was due, not to superior design, but to this characteristic armament and to the relatively high engine power. On the other hand, throughout the war the only stable machines were British. For observation work, night flying, and flight in fog and cloud the advantages of a stable machine are obvious. On the other hand, unstability, inasmuch as it favours rapid and unexpected manœuvres, was for a time regarded as an advantage in aerial fighting, but later experience proved that a well-designed aeroplane could be made stable and yet remain quick and light on the controls.

Seaworthiness, no less than air-worthiness, is required of the seaplane, and this implies a machine of considerable size and weight. Most of the best seaplanes in use in 1918 had a total weight of 4 tons or 5 tons each, a speed of nearly 100 miles, and engines of about 700 h.p. The machines used by the special aeroplane ships were principally small fast scouts, but one type was of sufficient size to carry an 18-in. torpedo. In 1918, 70 aeroplanes were carried by the fleet as part of the regular equipment.

Airships proved to be of great importance in connection with naval work. The smaller non-rigids were used for patrol duty along the coast and convoy service, and by their means a submarine could be detected and attacked while still at a considerable distance below the surface. The success achieved was extensive, and ships convoyed by airships were practically immune from submarine attack. The larger non-rigids served as scouts in naval operations. The S.S.Z. had a speed of 50 miles and a gross lift of about 2 tons; the North Sea type a lift of 11 tons and a speed of 60 miles.

Compared with the achievements in other directions the record of British work in connection with the development of rigid airships is not entirely satisfactory. In this field, where consistent policy and firmness of purpose were essential, the Admiralty vacillated strangely. The Mayfly, constructed at Barrow in 1910, was admittedly an experiment, and although an accident ended her career after the first few motoring tests, she had already served her purpose in providing the experience and data

necessary for a more perfect construction. Nothing further was done, however, until after the war had started. In Germany, on the other hand, painstaking plodding had built up success on the ruins of a dozen failures.

Improvements in the rate of climb of aeroplanes and the invention of the incendiary bullet brought an end to the effectiveness of the Zeppelin as a bomber, but as a scout in long range naval operations its influence remained considerable, and the recent successful journey of R. 34 indicates the possibilities of the rigid airship in times of peace. The useful load increases rapidly with size, and a ship 15 per cent. larger than R. 34 in linear dimensions could have carried 100 people to America.

What is popularly known as an invention, or an idea of revolutionary importance emanating from one person, has played relatively little part in the recent development of aeronautics. Success has been due to systematic investigation and to the combined effort of many scientific workers, trained designers, and practical constructors. With some exceptions, the same holds true in the case of engine construction. Inventions there have been, 8,000 are duly recorded in the files of the Air Inventions Committee, but equipment and armament and accessories appear to have offered most scope for brilliant new departures.

Several inventions notably influenced the course of the war. The successful manufacture of incendiary bullets put an end to the Zeppelin raids, tracer bullets increased the accuracy of aim, and synchronising gear made it possible to fire through the propeller at the rate of nearly 1,000 rounds per minute. A satisfactory self-sealing petrol tank was manufactured after many unsuccessful attempts, and greatly diminished the risk of fire. Much ingenuity was displayed in connection with bomb sighting and navigational instruments. Wireless telephone and directional wireless were introduced. A reliable turn indicator and improved compass made accurate navigation through clouds possible. Armoured aeroplanes were constructed; special machines were also designed for carrying 37-mm. quick-firing guns for use at the front and against submarines; these guns fired a 1½-lb. high explosive shell.

The increased efficiency of the anti-aircraft artillery and the high rate of climb of the defending machines put a check on daylight aeroplane raids, while at night and in mist both searchlights and guns could be trained on the enemy even if invisible by means of sound directors. A screen of kite balloons supporting nets formed part of the night defences of London, and justified its existence by the moral effect produced on the enemy pilots.

The use of airships near the fighting zone or within reach of enemy aeroplanes was impossible owing to the inflammable nature of the gas they contained, and in spite of all precautions the loss in kite balloons was serious. The proposal to replace the hydrogen by helium came from a member of the Board of Invention and Research, and in 1915 experiments were started with a view to the ultimate production of several million cubic feet per month. The boldness of the idea is best emphasised by the fact that at that time it took weeks to obtain the few cubic inches of gas required for the preliminary permeability tests. Progress was accelerated when American came into the war, and at the time of the armistice a supply of 350,000 cub. ft. per week was ensured.

The above outline of engineering activities during the war is both incomplete and imperfect. It may, however, serve to emphasise and illustrate the two features which characterised the period and made victory possible.

The first is: Large production, obtained by organisation, standardisation and co-operation.

The second is: Rapid progress resulting from the stimulus to research and invention and the immediate application of the results obtained.

The required organisation did not arise as a natural development of the pre-war industrial activity; it was called into being by dire necessity and applied with grim determination. Before the war the British nation was anti-militarist, non-scientific, and strongly individualistic. To achieve victory the nation accepted universal conscription, and submitted to the mixture of socialism and tyranny which necessity dictated. Under extreme pressure, scientific knowledge, technical skill, industrial ability, military and naval experience welded into a homogeneous and efficient organisation.

It is easy to disparage the effort or to point to defects, large or small, which tarnish the record, but the fact remains that, whereas in 1914 we were inferior to the enemy in every military asset except moral courage, in 1918 victory came as the result of mastery in practically all the thousand factors on which modern warfare depends.

The organisation involved the direct control of food, every essential raw material, shipping and transport; further, under the cloak of various euphemisms, it involved the indirect control of all available capital and labour. The capitalist was granted the privilege of receiving and paying the interest on the money required. High wages and the Military Conscription Act ensured an adequate supply of labour in the factories. And these things came to pass, not by tyrannical order of an all-powerful Government, but by the force of a great idea working within the nation.

II.—Industrial and Economic Reconstruction.

The peace declaration is the opening of a new act in the world's greatest drama, and the events of the next few years will decide the fate of many generations. The future is always the logical sequence of the past; it is the present which gives direction to the forces which are acting in virtue of the ideals which are operative. The world is emerging from a furnace, and the rigid constitution of civilisation, for a moment plastic, will harden in the mould we form. It is, therefore, the duty of each one of us to attempt to understand the transformation which is going on, and influence it in the right direction.

The principal feature of the day is the insistent craving for better and easier conditions of life; in popular language this is quite inaccurately expressed by a demand for higher wages and less work. The two aims are far from identical; in fact, a little consideration will show that in some respects they are contradictory.

The total remuneration received by a nation is measured by its production, and this law cannot be alterated or affected by legislation or revolution. On the other hand, the share received by a class or an individual is capable of adjustment within certain limits. Thus any class may increase its remuneration either by increasing the total production or by decreasing the remuneration received by the other classes. The capitalist who corners wheat, and the miner who corners coal, are examples of the latter method. No such limitations exist, however, with regard to the face value of the wages paid; by Act of Parliament all wages might be increased arbitrarily twentyfold, but as a result the cost of living would rise in a similar ratio.

Incalculable harm has been done by ignorance and wilful misrepresentation. During a generation the working classes have been told, and have firmly believed, that they receive but a tithe of the value of their work, and that the bulk goes to swell the fortune of the capitalistic class. The actual facts so far as engineering is concerned will be found in the address of my predecessor in this chair. On an average in pre-war days the share of the capitalist was one-ninth that of the workman. The actual position with regard to coal is now known to all. For each ton raised 19*s.* 5½*d.* goes for labour and a total of 2*s.* is paid as royalties, owners' profits, and owners' compensation. It is obvious that the 13*s.* rise in the miner's wages cannot be paid out of profits and royalties amounting to a total of 2*s.*, but the miners, who have been brought up to believe in the fabulous profits of the wicked duke, is quite ready to strike against the owners, the Government, and the laws of arithmetic.

These facts, though clearly established, are not easily credited by the working man; he may have received a penny for what he considers is the manufacture of an article and sees it selling for a shilling in a shop. He forgets that the price must include, not only his wage, but that of the men in the mine, the smelting works and the rolling mill, who provided the material in the shape required, the wages of the men who built the factory in which he works and made the machine he uses, the wages of transport workers, packers, shop assistants, advertising agents, printer, papermakers, &c.; and that, finally, some minute fraction of a farthing might with justice be allotted to the engineer who designed the machine or invented the process. The general position, though similar, cannot, unfortunately, be followed so closely; the limitations, however, are clear. The income of the United Kingdom per head of the population was before the war about 50*l.* If, therefore, the State were run on completely communistic lines, and if under these conditions there were no reduction either in the working hours or the output our wages would average a sovereign a week each, and we could buy our goods at pre-war prices.*

The above considerations indicate that a real improvement in material welfare is necessarily associated with increased production. The needs of mankind are many, its desires are unlimited, and for this reason general overproduction need never arise. Many circumstances may, however, lead to uneven balance, and unfortunately, when this occurs, the producers of the commodity which is in excess are penalised, and those responsible for a deficiency are rewarded. The instability is fostered and increased by speculation, and, although it forms the most powerful check on national prosperity, no serious effort has yet been made to apply a remedy.

I am inclined to think that two of the most important problems of our time relate to economic balance and increased production. The solution in the former case is dependent on the statesman, the economist, and the business man, in the latter on the combined efforts of various branches of applied science, and more especially on engineering.

At one time production was directly dependent on muscular effort; it is now mainly influenced by equipment, organisation and skill. Increased production does not necessarily imply harder work or longer hours; it can be secured by improvements in method and machinery, but only with the willing co-operation of all concerned.

Before the war the Americans were far ahead of us in standardisation and specialised machinery. The American clock and the Ford car are two well-known examples. During the war we adopted and developed these methods. As a result, although the cost of all materials increased considerably, although the wages more than doubled and the profits were more than adequate, the cost was in many cases reduced. Thus the 18-pounder shell fell from 22*s.* to 12*s.*, the Lewis gun from 165*l.* to 62*l.* The importance of standardisation has been fully realised by the manufactures of this country, and as a result we may hope to see a general reduction in cost.

The economic value of an individual depends exclusively on the nature, quality and quantity of his output, and his remuneration should correspond to his economic value. The rule is simple, its application would solve most of the problems which vex the present generation, but no scheme has yet been evolved to make its application possible.

There can be no doubt that in this respect our present system is a complete failure. It has been built up casually in the course of the industrial warfare of the last twenty years, and each side, regardless of consequences, has entrenched itself in any position won. The result is a system nearly perfect from the point of view of offence and defence, well arranged for mutual destruction, but, like the trenches in France, unsuitable for use in time of peace.

The minimum wage is beneficial in so far as it prevents sweating, but in two other respects its consequences are most unfortunate. Under the operation of this rule the man whose value is a fraction below the minimum is unemployed and economically unemployable. Further, the minimum wage becomes the standard wage, and the better men are inadequately paid. Both causes lead to decreased production. The weaker or less skilful men drift into enforced idleness, and become a charge to the community under the heading of charity, poor-law, or some newly-invented euphemism. The better men, finding extra effort uncompensated, drop to an ever-decreasing minimum. Small output is in most cases the result of inadequate incentive rather than active restriction. Promotion by seniority is an example of a similar cause, producing similar effects in other classes of the community.

Among the professional and business classes the remuneration is proportional to the skill and to the effort; a barrister, an engineer, or a merchant has neither minimum wage nor fixed maximum output, and, the vagaries of chance excepted, generally speaking gets what he is worth. At the two extremes stand riches and starvation, and the economic world can offer no stronger motive forces than the allurements of the one, the fear of the other. There is no absolute reason why the working man should not be offered the same incentives to hard work and progress, but up to the present most efforts have tended in the opposite direction. Any form of payment by result is viewed with indifference or distrust by the unions, and past experience with piece work explains that attitude. There has been a disposition for employers to make large individual earnings an excuse for cutting rates. Errors in rate fixing may easily arise, and in certain cases special investigation might be necessary, but the advantages of high individual production are so great to both employer and employed that in all cases of doubt the higher rate should be maintained. In this connection the method of time-study first developed by Taylor in America and the various systems of payment by results which have been successfully applied deserve careful consideration.

Another important but difficult subject is the distinction drawn between skilled and unskilled labour. The experience gained during the war has proved that many operations scheduled as skilled work could be effectively performed by women who had only received a few weeks' special instruction. The oft-repeated demand for equal opportunity for all becomes a senseless parrot cry if it does not imply that an individual has the right to undertake better remunerated work if qualified to do so. It is a misconception which leads the skilled worker to believe that such a concession would reduce his earnings. Just as it is clear that if labourers and skilled men were grouped together at a uniform wage, that wage would necessarily be lower than the present minimum for skilled work, so also the separation of tasks which require but a nominal period of training would increase the rate of remuneration available for the really skilled man.

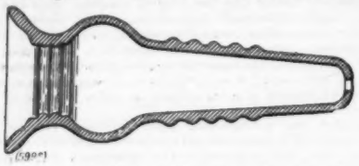
I have drawn attention to some of the difficulties which must be solved if the country is to emerge from the present crisis prosperous or even solvent. There is little doubt that an elucidation is possible, but it can only be evolved by the honest and intelligent collaboration of all parties concerned, a task rendered difficult or impossible by mutual distrust and class hatred. Class differences there are, and always will be; they exist as the result of breeding, education and environment, but they do not extend to the fundamental characteristics of humanity. Many dukes and many miners are lazy; most capitalists and most trade unionists are greedy; all men, with a few exceptions, are selfish. The war has shown that lazy, greedy and selfish men will die or even work for their country in a great exigency, but there is a limit to and a reaction after any profound emotional stimulus, and the present unrest and dissatisfaction are but normal symptoms. A satisfactory economic system can only be based on natural human impulses, and of these the most fundamental is self-preservation, or, more generally, self-interest. Increased production is at the present moment the most pressing national need, but it will become effective only when for every man increased production becomes the talisman by which his paper wages can be turned to gold.

* This statement is optimistic in so far as it does not take account of war losses.

The Institution of Automobile Engineers.—The first meeting of the session of the Institution of Automobile Engineers will be held on Wednesday, October 1, 1919, at the Royal Society of Arts, John-street, Adelphi, W.C., at 8 p.m., when Mr. Thomas Clarkson, M.Inst.C.E., will deliver his presidential address. Amongst the papers which have been promised to the Institution for the forthcoming session are the following: "Valve Failures in Petrol Engines," by Dr. L. Aitchison; "Car Design and Car Usage considered from the Standpoint of the Majority of Owner-Drivers," by Mr. E. N. Duffield; "Producer Gas as Applied to Vehicle Propulsion," by Lieutenant-Colonel D. J. Smith; "Cast-Iron in Relation to the Automobile Industry," by Mr. J. E. Hurst; "Some Experiments on Supercharging for High-Speed Engines," by Mr. H. R. Ricardo; "Air-Cooling of Engines," by Dr. A. H. Gibson; "Gear Cutting," by Mr. P. J. Worsley; "Inertia Torque in Crankshafts," by Mr. F. A. S. Acres; "The Final Drive of the Motor Cycle," by Mr. E. Caudwell; "The Process of Ignition," by Mr. A. P. Young and Mr. H. Warren; and "Steel Tubes—their Manipulation and Use in Construction," by Mr. W. W. Hackett.

THE "BI-JET" HOSE PIPE NOZZLE.

We give below a sectional view of a very simple and effective device for enabling a hose pipe to deliver either a well-defined jet or a soft flow of water at the pleasure of the user. It will be seen that the nozzle is a brass casting suitably formed for insertion in the hose pipe, and having at its inner end a hole through which a simple jet can be delivered. At its outer end the casting is enlarged to form a spherical chamber with a bell mouthed orifice. The throat of the casting leading to the spherical chamber is corrugated internally.



When the water is turned on to a hose fitted with this nozzle a clean well-formed jet is delivered, but if the hand be placed momentarily on the orifice of the nozzle this discharge changes at once to a soft flow. On the other hand, if this soft flow is being delivered a slight sweeping jerk at once causes the clean jet to be restored. For car or carriage washing we have found the device to be exceedingly convenient, and as there are no loose parts there is nothing to get out of order. The device, which has been named the "Bi-jet," is being made by Messrs. Brown Brothers, Ltd., 22 to 34, Great Eastern Street, London, E.C. 2.

PATTERNMAKERS' WOOD-GRINDING MACHINES.

In the majority of pattern shops the wood-grinding machinery is used by all the patternmakers as circumstances demand, the object being to reduce the lengthy hand operations which occur during the manufacture and building up of patterns. The machines, therefore, supplement the bench work in addition to preparing and finishing components that come direct from the bandsaws and other machines. It will be recognised that such machines are general utility tools and do not require, in the absence of considerable repetition work, special wood-working machinists. The design carried out in the two wood-grinding machines illustrated in Figs. 1 and 2, annexed, and manufactured by Messrs. Wadkin and Co., of Leicester, adequately and economically meet the needs of all classes of pattern work, the machines are easily manipulated, and having guides and labour-saving devices, can be quickly and accurately adjusted by the patternmaker.

The combined disc and vertical reciprocating drum wood-grinder is illustrated in Fig. 1. This machine will grind to a finish, flat or external curved surfaces on the disc, and internal and external curved surfaces on the reciprocating drum, and in both cases with either square or bevelled edges. The main frame is a single casting, with a large base. A steel shaft running in adjustable phosphor-bronze bearings, carries the steel disc in such a manner that it can be removed and on being replaced runs perfectly true. Fast and loose driving pulleys enable the disc to be started, and stopped. The vertical drum at the opposite end of the machine is carried in a vertical sliding frame, arranged to reciprocate vertically from a suitably-geared crankshaft. The drums are of timber, split, covered in felt and held on the spindle between cone cups, which method enables the drums to be changed by releasing one nut. A simple grip arrangement holds the abrasive paper perfectly tight. The spindle is steel, and runs in adjustable phosphor-bronze bearings, and an adjustable thrust bearing takes the weight of the spindle. The work-tables are arranged to cant above and below the horizontal; the disc table carries a swivelling fence, which can be used either right or left-handed, the principal angles being clearly marked on the table. The drum-table is provided with gap plates to accommodate various sizes of drums. The countershaft is in the base of the machine and the belt drives the disc and drum inside the body, making a perfectly simple and effective arrangement. Every care has been taken in designing this machine to ensure continuous service, the question of lubrication has been given careful consideration, and the methods employed ensure no grit entering the bearings and vertical slide. The machine shown is fitted with an effective and self-contained dust-collecting system which keeps the machine and operator free from this annoyance. Two sizes of machine are manufactured, one with a 22-in. diameter disc, which requires a total floor space of 4 ft. 8 in. by 2 ft. 2 in., and the other with a 30-in. diameter disc requiring a total floor space of 5 ft. 4 in. by 2 ft. 10 in.

The vertical reciprocating belt wood-grinder is shown in Fig. 2, and is suitable for all kinds of flat and curved work with square and bevelled edges. For finishing flat and irregular surfaces, internal and external scroll work to fine limits, the design offers many advantages.

The main frame of the machine is a cored casting carried on suitable stands, in which are two long bosses through which the reciprocating belt frame columns slide vertically. The reciprocating frame is provided at one end with adjustable phosphor-bronze bearings, carrying the large cast-iron belt drum and shaft. The small belt drum is arranged to run in dust proof ball bearings, carried in a special swivelling bracket, which slides backwards and forwards by lever, for tensioning the belt; it is made of steel and covered with rubber properly vulcanised on. The swivelling screw adjustment allows the belt being tracked to run perfectly true on the drum; this latter adjustment is practically only required when a new belt is put on.

The vertical reciprocating motion is obtained by a double-ended crankshaft, operating two adjustable lifting levers, which are applied to the vertical sliding columns of frame in conjunction with balancing springs, and in such a manner that the vertical lift of the frame at all times is positive and properly timed at both ends; all pin joints are adjustable for wear.

The machine is fitted with three work-tables, one for the large drum, one for the small drum, and another at the side of the abrasive belt. The two latter tables cant above and below the horizontal, enabling bevelled work to be carried out, and are adjustable to or from the belt. The side table is fitted with a universal swivelling fence, enabling plain and compound angular work to be easily produced.

The machine is supplied with the usual accessories, and is complete with a self-contained countershaft with loose and fast pulley and striking gear.

PATTERNMAKERS' WOOD-GRINDING MACHINES.

CONSTRUCTED BY MESSRS. WADKIN AND CO., ENGINEERS, LEICESTER.

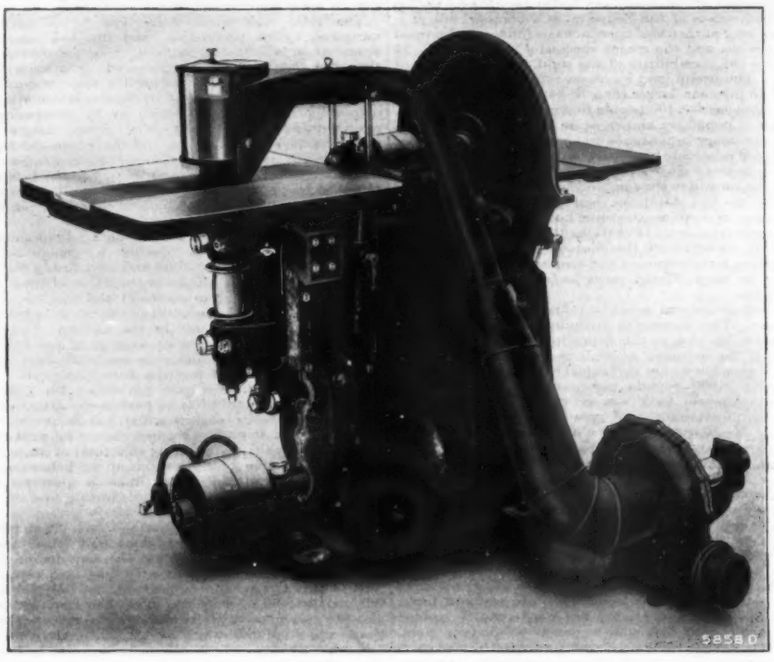


FIG. 1.

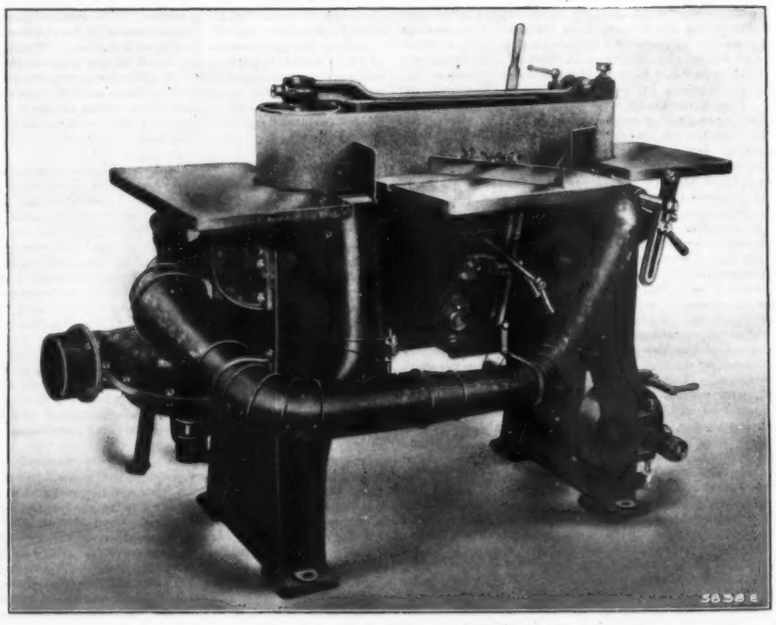


FIG. 2.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

Address by the Hon. Sir CHARLES A. PARSONS, K.C.B., M.A., LL.D., D.SC., F.R.S., *President.*

THREE years of anxiety and stress have passed since the last meeting of the British Association. The weight of the struggle which pressed heavily upon us at the time of the Newcastle meeting in 1916 had increased so much in intensity by the spring of 1917 that the council, after consultation with the Local Committee at Bournemouth, finally decided to cancel the summer meeting of that year. This was the first time in the history of the Association that an annual meeting was not held.

We all rejoice to feel that the terrible ordeal through which the whole Empire has been passing has now reached its final phases, and that during the period of reorganisation, social and industrial, it is possible to resume the annual meetings of the Association under happier conditions. We have gladly and with much appreciation accepted the renewed invitation of our friends and colleagues at Bournemouth.

We are gathered together at a time when, after a great upheaval, the elemental conditions of organisation of the world are still in flux, and we have to consider how to mould and influence the recrystallisation of these elements into the best forms and most economic rearrangements for the benefit of civilisation. That the British Association has exerted great influence in guiding the nation towards advancement in the sciences and arts in the most general sense there can be no question, and of this we may be assured by a study of its proceedings in conjunction with the history of contemporary progress. Although the British Association cannot claim any paramount prerogative in this good work, yet it can certainly claim to provide a free arena for discussion where in the past new theories in Science, new propositions for beneficial change, new suggestions for casting aside fetters to the advancement in science, art and economics have first seen the light of publication and discussion.

For more than half a century it has pleaded strongly for the advancement of science and its application to the arts. In the yearly volume for 1855 will be found a report in which it is stated that "The objects for which the Association was established have been carried out in three ways: First, by requisitioning and printing reports on the present state of different branches of science; secondly, by granting sums of money to small committees or individuals, to enable them to carry on new researches; thirdly, by recommending the Government to undertake expeditions of discovery, or to make grants of money for certain and national purposes, which were beyond the means of the Association." As a matter of fact it has, since its commencement, paid out of its own funds upwards of 80,000*l.* in grants in aid of research.

DEVELOPMENTS PRIOR TO THE WAR.

It is twenty-nine years since an engineer, Sir Frederick Bramwell, occupied this chair and discoursed so charmingly on the great importance of the next to nothing, the importance of looking after little things which, in engineering, as in other walks of life, are often too lightly considered.

The advances in engineering during the last twenty years are too many and complex to allow of their description, however short, being included in one address, and, following the example of some of my predecessors in this chair, I shall refer only to some of the most important features of this wide subject. I feel that I cannot do better than begin by quoting from a speech made recently by Lord Inchcape, when speaking on the question of the nationalisation of coal: "It is no exaggeration to say that coal has been the maker of modern Britain, and that those who discovered and developed the methods of working it have done more to determine the bent of British activities and the form of British society than all the Parliaments of the past 120 years."

James Watt.—No excuse is necessary for entering upon this theme, because this year marks the hundredth anniversary of the death of James Watt, and, in reviewing the past, it appears that England has gained her present proud position by her early enterprise and by the success of the Watt steam engine, which enabled her to become the first country to develop her resources in coal, and led to the establishment of her great manufactures and her immense mercantile marine

The laws of steam which James Watt discovered are simply these: That the latent heat is nearly constant for different pressures within the ranges used in steam engines, and that, consequently, the greater the steam pressure and the greater the range of expansion the greater will be the work obtained from a given amount of steam. Secondly, as may now seem to us obvious, that steam from its expansive force will rush into a vacuum. Having regard to the state of knowledge at the time, his conclusions appear to have been the result of close and patient reasoning by a mind endowed with extraordinary powers of insight into physical questions, and with the faculty of drawing sound practical conclusions from numerous experiments devised to throw light on the subject under investigation. His resource, courage and devotion were extraordinary.

In commencing his investigations on the steam engine he soon discovered that there was a tremendous loss in the Newcomen engine, which he thought might be remedied. This was the loss caused by condensation of the steam on the cold metal walls of the cylinder. He first commenced by lining the walls with wood, a material of low thermal conductivity. Though this improved matters, he was not satisfied; his intuition probably told him that there should be some better solution of the problem, and doubtless he made many experiments before he realised that the true solution lay in a condenser separate from the cylinder of the engine. It is easy after discovery to say, "How obvious and how simple," but many of us here know how difficult is any step of advance when shrouded by unknown surroundings, and we can well appreciate the courage and the amount of investigation necessary before James Watt thought himself justified in trying the separate condenser. But to us now, and to the youngest student who knows the laws of steam as formulated by Carnot, Joule and Kelvin, the separate condenser is the obvious means of constructing an economical condensing engine.

Watt's experiments led him to a clear view of the great importance of securing as much expansion as possible in his engines. The materials and appliances for boiler and machine construction were at that time so undeveloped that steam pressures were practically limited to a few pounds above atmospheric pressure. The cylinders and pistons of his engines were not constructed with the facility and accuracy to which we are now accustomed, and chiefly for these reasons expansion ratios of from two to threefold were the usual practice. Watt had given to the world an engine which consumed from 5 lb. to 7 lb. of coal per horse-power-hour, or one-quarter of the fuel previously used by any engine. With this consumption of fuel its field under the conditions prevailing at the time was practically unlimited. What need was there, therefore, for commercial reasons, to endeavour still further to improve the engine at the risk of encountering fresh difficulties and greater commercial embarrassments? The course was rather for him and his partners to devote all their energy to extend the adoption of the engine as it stood, and this they did, and to the Watt engine, consuming from 5 lb. to 7 lb. of coal per horse-power, mankind owes the greatest permanent advances in material welfare recorded in history.

With secondary modifications, it was the prime mover in most general use for eighty years—*i.e.*, till the middle of last century. It remained for others to carry the expansion of steam still further in the compound, triple, and, lastly, in the quadruple expansion engine, which is the most economical reciprocating engine of to-day.

Watt had considered the practicability of the turbine. He writes to his partner, Boulton, in 1784: "The whole success of the machine depends on the possibility of prodigious velocities. In short, without God makes it possible for things to move them 1,000 ft. per second, it cannot do us much harm." The advance in tools of precision, and a clearer knowledge of the dynamics of rotating bodies, have now made the speeds mentioned by Watt feasible, and indeed common, everyday practice.

Turbines.—The turbine of to-day carries the expansion of steam much further than has been found possible in any reciprocating engine, and owing to this property it has surpassed it in the economy of coal, and it realises to the fullest extent Watt's ideal of the expansion of steam from the boiler to the lowest vapour pressure obtainable in the condenser.

Among the minor improvements which in recent years have conduced to a higher efficiency in turbines are the more accurate curvature of the blades to avoid eddy losses in the steam, the raising of the peripheral velocities of the blades to nearly the velocity of the steam impinging upon them, and details of construction to reduce leakages to a minimum. In turbines of 20,000 h.p. to 30,000 h.p. 82 per cent. of the available energy in the steam is now obtainable as brake horse-power; and with a boiler efficiency of 85 per cent. the thermodynamic efficiency from the fuel to the electrical output of the alternator has reached 23 per cent., and shortly may reach 28 per cent., a result rivalling the efficiency of internal-combustion engines worked by producer gas.

During the twenty years immediately preceding the war turbo-generators had increased in size from 500 kw. to 25,000 kw., and the consumption of steam had fallen from 17 lb. per kilowatt-hour to 10·3 lb. per kilowatt-hour. Turbines have become the recognised means of generating electricity from steam on a large scale, although they have not superseded the Watt engine for pumping mines or the drawing of coal, except in so far as it is a means for generating electricity for these purposes. In the same period the engine power in the mercantile marine had risen from 3,900 of the King Edward to 75,000 of the Mauretania.

As regards the Royal Navy, the engine power of battleships, prior to the war, had increased from 12,000 i.h.p. to 30,000 shaft horse-power, while the speed advanced from 17 knots to 23 knots, and during the war, in ships of the Queen Elizabeth class, the power amounted to 75,000 shaft horse-power, with a speed of 25 knots. In cruisers similar advances were made. The indicated horse-power of the Powerful was 25,000, while the shaft horse-power of the Queen Mary was 78,000, with a speed of 28 knots. During the war the power obtained with geared turbines in the Courageous class was 100,000 shaft horse-power, with a speed of 32 knots, the maximum power transmitted through one gear wheel being 25,000 h.p., and through one pinion 15,500 h.p., while in destroyers, speeds up to 39 knots have been obtained. The aggregate horse-power of war and mercantile turbined vessels throughout the world is now about 35,000,000.

These advances in power and speed have been made possible mainly by the successive increase in economy and diminution of weight derived from the replacement of reciprocating engines by turbines direct-coupled to the propellers and, later, by the introduction of reduction gearing between the turbines and the propellers; also by the adoption of water-tube boilers and of oil fuel. With these advances the names of Lord Fisher, Sir William White and Sir Henry Oram will always be associated.

The British Navy has led the world for a century and more. Lord Fisher has recently said that many of the ships are already obsolete and must soon be replaced if supremacy is to be maintained: and there can be no question that to guide the advance and development on the best lines continuous scientific experiment, though costly at the time, will prove the cheapest in the long run.

The Work of Sir William White.—With the great work of the Royal Navy fresh in our minds, we cannot but recall the prominent part taken by the late Sir William White in its construction. His sudden death, when president-elect for 1913, lost to the nation and to the Association the services of a great naval architect who possessed remarkable powers of prevision and dialectic. He was Chief Constructor to the Admiralty from 1885 to 1901; and largely to him was due the efficiency of our vessels in the Great War.

White often referred to the work of Brunel as the designer of the Great Eastern, and spoke of him as the originator of the cellular construction of the bottoms of ships, since universally adopted, as a means of strengthening the hull and for obtaining additional safety in case of damage. Scott Russell was the builder of this great pioneer vessel, the forerunner of the Atlantic liners, and the British Association may rightly feel satisfaction in having aided him when a young man by pecuniary grants to develop his researches into the design and construction of ships and the wave-line form of hull which he originated, a form of special importance in paddle-wheel vessels.

So much discussion has taken place in the last four years as to the best construction of ship to resist torpedo attacks that it is interesting to recall briefly at the present time what was said by White in his Cantor Lectures to the Royal Society of Arts in 1906: "Great attention has been bestowed upon means of defence against underwater torpedo attacks. From the first introduction of torpedoes it was recognised that extreme watertight subdivision in the interior of warships would be the most important means of defence. Experiments have been made with triple watertight skins forming double cellular sides, the compartments nearest the outer bottom being filled, in some cases with water, coal, cellulose, or other materials. Armour plating has been used both on the outer bottom and on inner skins." He also alludes to several Russian ships which were torpedoed by the Japanese, and he concludes by saying: "Up to date the balance of opinion has favoured minute watertight subdivisions and comparatively thin watertight compartments, rather than the use of internal armour, whose use, of course, involves large expenditure of weight and cost."

The present war has most amply confirmed his views and conclusions, then so lucidly and concisely expressed.

While on the subject of steamships, it may perhaps be opportune to say one word as to their further development. The size of ships had been steadily increasing up to the time of the war, resulting in a reduction of power required to propel them per ton of displacement. On the other hand, thanks to their greater size and more economical machinery, speeds have been increased when the traffic has justified the greater cost. The limiting factor to further increase in size is the depth of water in the harbours. With this restriction removed there is no obstacle to building ships up to 1,000 ft. in length or more, provided the volume and character of the traffic are such as to justify the capital outlay.

Tungsten Steel.—Among other important pre-war developments that have had a direct bearing upon the war, mention should be made of the discovery and extensive use of alloys of steel. The wonderful properties conferred upon steel by the addition of tungsten were discovered by Mushet in 1868,* and later this alloy was investigated and improved by Maunsel White and Taylor, of Philadelphia. The latter showed that the addition of tungsten to steel has the following effect That after the steel has been quenched at a very high temperature near its melting-point it can be raised to a much higher temperature than is possible with ordinary carbon tool steel, without losing its hardness and power of cutting metal. In other words, it holds the carbon more tenaciously in the hardened state, and hence tungsten steel tools, even when red hot, can cut ordinary mild steel. It has revolutionised the design of machine tools and has increased the output on heavy munition work by 100 per cent., and in ordinary engineering by 50 per cent.

The alloys of steel and manganese with which Sir Robert Hadfield's name is associated have proved of utility in immensely increasing the durability of railway and tramway points and crossings, and for the hard teeth of machinery for the crushing of stone and other materials, and, in fact, for any purposes where great hardness and strength are essential.

Investigation of Gaseous Explosions.—Brief reference must also be made—and it will be gratifying to do so—to the important work of one of the committees of the British Association appointed in 1908, under the chairmanship of the late Sir William Preece, for the investigation of gaseous explosions, with special reference to temperature. The investigations of the committee are contained in seven yearly reports up to 1914. Of the very important work of the committee I wish to refer to one investigation in particular, which has proved to be a guiding star to the designers and manufacturers of internal-combustion engines in this country. The members of the committee more directly associated with this particular investigation were Sir Dugald Clerk, Professor Callendar, and the late Professor Bertram Hopkinson.

The investigation showed that the intensity of the heat radiated by the incandescent gases to the walls of the cylinder of a gas engine increases with the size of the

* Who has not perhaps been sufficiently credited with his share in making the Bessemer process a practical success.

cylinder, the actual rate of this increase being approximately proportional to the square root of the depth of the radiating incandescent gas; the intensity was also shown to increase rapidly with the richness of the gas. It suffices now to say that the heat in a large cylinder with a rich explosive mixture is so intense that the metal eventually cracks. The investigation shows why this occurs, and by doing so has saved enormous sums to the makers of gas and oil engines in this country, and has led them to avoid the large cylinder, so common in Germany before the war, in favour of a multiplicity of smaller cylinders.

In coming to this section of my address, which deals with science and the war, I am reminded that in the course of his presidential address to Section G, in 1858, Lord Rosse said: "Another object of the Mechanical Section of the Association has been effected—the importance of engineering science in the service of the State has been brought more prominently forward. There seems, however, something still wanting. Science may yet do more for the Navy and Army if more called upon."

Comparatively recently, too, Lord French remarked: "We have failed during the past to read accurately the lessons as regards the fighting of the future which modern science and invention should have taught us."

In view of the eminent services which scientists have rendered during the war, I think that we may be justified in regarding the requirement stated by Lord Rosse as having at last been satisfied, and also in believing that such a criticism as Lord French rightly uttered will not be levelled against the country in the future.

Though British men of Science had not formerly been adequately recognised in relation to war and the safety of their country, yet at the call of the sailors and the soldiers they wholeheartedly, and with intense zeal devoted themselves to repair the negligence of the past, and to apply their unrivalled powers and skill to encounter and overcome the long-standing machinations of the enemy. They worked in close collaboration with the men of science of the Allied Nations, and eventually produced better war material, chemicals, and apparatus of all kinds for vanquishing the enemy and the saving of our men than had been devised by the enemy during many years of preparation planned on the basis of a total disregard of treaties and the conventions of war.

Four years is too short a time for much scientific invention to blossom to useful maturity, even under the forced exigencies of war and Government control. It must be remembered that in the past the great majority of new discoveries and inventions of merit have taken many years—sometimes generations—to bring them into general use. It must also be mentioned that in some instances discoveries and inventions are attributable to the general advance in science and the arts which has brought within the region of practical politics an attack on some particular problem. So the work of the scientists during the war has perforce been directed more to the application of known principles, trade knowledge, and properties of matter to the waging of war, than to the making of new and laborious discoveries; though, in effecting such applications, inventions of a high order have been achieved, some of which promised to be of great usefulness in times of peace.

The advance of science and the arts in the last century had, however, wrought a great change in the implements of war. The steam engine, the internal-combustion engine, electricity, and the advances in metallurgy and chemistry had led to the building up of immense industries which, when diverted from their normal uses, have produced unprecedented quantities of war material for the purposes of the enormous armies, and also for the greatest Navy which the world has ever seen.

The destructive energy in the field and afloat has multiplied many hundredfold since the time of the Napoleonic wars; both before and during the war the size of guns and the efficiency of explosives and shell increased immensely, and many new implements of destruction were added. Modern science and engineering enabled armies unprecedented in size, efficiency and equipment, to be drawn from all parts of the world and to be concentrated rapidly in the fighting line.

To build up the stupendous fighting organisation, ships have been taken from their normal trade routes, locomotives and material from the home railways, the normal manufactures of the country have been largely diverted to munitions of war; the home railways, tramways, roads, buildings and constructions, and material of all kinds have been allowed to depreciate. The amount of depreciation in roads and railways alone has been estimated at 400,000,000*l.* per annum at present prices. Upon the community at home a very great and abnormal strain has been thrown, notwithstanding the increased output per head of the workers derived from modern methods and improved machinery. In short, we have seen for the first time in history nearly the whole populations of the principal contending nations enlisted in intense personal and collective effort in the contest, resulting in unprecedented loss of life and destruction of capital.

A few figures will assist us to realise the great difference between this war and all preceding wars. At Waterloo, in 1815, 9,044 artillery rounds were fired, having a total weight of 37·3 tons, while on one day during the last offensive in France, on the British front alone, 943,837 artillery rounds were fired, weighing 18,080 tons—over 100 times the number of rounds, and 485 times the weight of projectiles. Again, in the whole of the South African War, 273,000 artillery rounds were fired, weighing approximately 2,800 tons; while during the whole war in France, on the British front alone, over 170,000,000 artillery rounds were fired, weighing nearly 3,500,000 tons—622 times the number of rounds, and about 1,250 times the weight of projectiles.

However great those figures in connection with modern land artillery may be, they become almost insignificant when compared with those in respect of a modern naval battle squadron. The Queen Elizabeth when firing all her guns discharges 18 tons of metal and develops 1,870,000 ft.-tons of energy. She is capable of repeating this discharge once every minute, and when doing so develops by her guns an average of 127,000 effective horse-power, or more than one and a half times the power of her propelling machinery; and this energy is five times greater than the maximum average energy developed on the Western front by British guns. Furthermore, if all her guns were fired simultaneously, they would for the instant be developing energy at the rate of 13,132,000 h.p. From these figures we can form some conception of the vast destructive energy developed in a modern naval battle.

ENGINEERING AND THE WAR.

With regard to the many important engineering developments made during the war, several papers by authorities are announced in the syllabus of papers constituting the sectional proceedings of this year's meeting, which deal with "Tanks," "Scientific Progress of Aviation During the War," "Airships," "Directional Wireless, with Special Reference to Aircraft," "Wireless in Aircraft," "Wireless Telegraphy During the First Three Years of the War," "Submarine Mining," "Emergency Bridge Construction," and "The Paravane." Accordingly, it is quite unnecessary here to particularise further except in the few following instances:

Sound-ranging and Listening Devices.—Probably the most interesting development during the war has been the extensive application of sound-listening devices for detecting and localising the enemy. The Indian hunter puts his ear to the ground to listen for the sound of the footsteps of his enemy. So in modern warfare science has placed in the hands of the sailor and soldier elaborate instruments to aid the ear in the detection of noises transmitted through earth, water, air, or ether, and also in some cases to record these sounds graphically or photographically, so that their character and the time of their occurrence may be tabulated.

The sound-ranging apparatus developed by Professor Bragg and his son, by which the position of an enemy gun can be determined from electrically-recorded times at which the sound wave from the gun passes over a number of receiving stations, has enabled our artillery to concentrate their fire on the enemy's guns, and often to destroy them.

The French began experimenting in September, 1914, with methods of locating enemy guns by sound. The English section began work in October, 1915, adopting the French methods in the first instance. By the end of 1916 the whole front was covered, and sound-ranging began to play an important part in the location of enemy batteries. During 1917 locations by sound-ranging reached about 30,000 for the whole army, this number being greater than that given by any other means of location. A single good set of observations could be relied upon to give the position of an enemy gun to about 50 yards at 7,000 yards range. It could also be carried on during considerable artillery activity.

The apparatus for localising noises transmitted through the ground has been much used for the detection of enemy mining and countermining operations. Acoustic tubes, microphones, and amplifying valves have been employed to increase the volume of very faint noises.

For many years before the war the Bell Submarine Signalling Company, of which Sir William White was one of the early directors, used submerged microphones for detecting sound transmitted through the water, and a submerged bell for sending signals to distances up to 1 mile. With this apparatus passing ships could be heard at a distance of nearly a mile when the sea was calm and the listening vessel stationary.

Of all the physical disturbances emitted or produced by a moving submarine, those most easily detected, and at the greatest distance, are the pressure waves set up in the water by vibrations produced by the vessel and her machinery. A great variety of instruments have been devised during the war for detecting these noises, depending on microphones and magnetophones of exceedingly high sensitivity. Among them may be particularly mentioned the hydrophones devised by Captain Ryan and Professor Bragg, being adaptations of the telephone transmitter to work in water, instead of air. These instruments, when mounted so as to rotate, are directional, being insensitive to sound waves whose front is perpendicular to the plane of the diaphragm, and giving the loudest sound when the diaphragm is parallel to the wave front.

Another preferable method for determining direction is to use two hydrophones coupled to two receivers, one held to each ear. This is called the biaural method, and enables the listener to recognise the direction from which the sound emanates.

When the vessel is in motion or the sea is rough the water noises from the dragging of the instrument through the water and from the waves striking the ship drown the noises from the enemy vessel, and under such conditions the instruments are useless. The assistance of eminent biologists was of invaluable help at this juncture. Experiments were made with sea lions by Sir Richard Paget, who found that they have directional hearing under water up to speeds of 6 knots. Also Professor Keith explained the construction of the hearing organs of the whale, the ear proper being a capillary tube, too small to be capable of performing any useful function in transmitting sound to the relatively large aural organs, which are deep set in the head. The whale, therefore, hears by means of the sound waves transmitted through the substance of the head. It was further seen that the organs of hearing of the whole to some degree resembled the hydrophone.

The course now became clear. Hollow towing bodies in the form of fish or porpoises were made of celluloid, varnished canvas, or very thin metal, and the hydrophone suitably fixed in the centre of the head. The body is filled with water, and the cable towing the fish contains the insulated leads to the observer on board the vessel. When towed at some distance behind the chasing ship disturbing noises are small, and enemy noises can be heard up to speeds of 14 knots, and at considerable distances. Thermionic amplifying valves have been extensively used, and have added much to the sensitiveness of the hydrophone in its many forms.

After the loss of the Titanic by collision with an iceberg, Lewis Richardson was granted two patents in 1912 for the detection of above-water objects by their echo in the air, and under-water objects by their echo transmitted through the water. The principles governing the production and the concentration of beams of sound are described in the specification, and he recommends frequencies ranging from 4,786 to 100,000 complete vibrations per second, and also suggests that the rate of approach or recession from the object may be determined from the difference in the pitch of the echo from the pitch of the blast sent out. Hiram Maxim also suggested similar apparatus a little later.

The echo method of detection was not, however, practically developed until French and English scientists, with whom was associated Professor Langevin, of the College de France, realising its importance for submarine detection, brought the apparatus to a high degree of perfection and utility shortly before the armistice. Now with beams of high-frequency sound waves, it is possible to sweep the seas for the detection of any submerged object, such as icebergs, submarines, surface vessels, and rocks; they may also be used to make soundings. It enables a chasing ship to pick up and close in on a submarine situated more than a mile away.

The successful development of sound-ranging apparatus on land led to the suggestion by Professor Bragg that a modified form could be used to locate under-water explosions. It has been found that the shock of an explosion can be detected hundreds of miles from its source by means of a submerged hydrophone, and that the time of the arrival of the sound wave can be recorded with great precision. At the end of the war the sound-ranging stations were being used for the detection of positions at sea, required for strategical purposes. The same stations are now being used extensively for the determination of such positions at sea as light vessels, buoys which indicate channels, and obstructions such as sunken ships. By this means ships steaming in fog can be given their positions with accuracy for ranges up to 500 miles.

Among the many other important technical systems and devices brought out during the war which will find useful application under peace conditions as aids to navigation I may mention directional wireless, by which ships and aircraft can be given their positions and directed, and on this subject we are to have a paper in Section G.

Leader gear, first used by the Germans to direct their ships through their minefields, and subsequently used by the Allies, consists of an insulated cable laid on the bottom of the sea, earthed at the further end, and through which an alternating current is passed. By means of delicate devices installed on a ship, she is able to follow the cable at any speed with as much precision as a railless electric 'bus can follow its trolly wire. Cables up to 50 miles long have been used, and this device promises to be invaluable to ships navigating narrow and tortuous channels and entering or leaving harbours in a fog.

Aircraft.—It may be justly said that the development* in aircraft design and manufacture is one of the astonishing engineering feats of the war. In August, 1914, the British Air Services possessed a total of 272 machines, whereas in October, 1918, just prior to the armistice, the Royal Air Force possessed over 22,000 effective machines. During the first twelve months of the war the average monthly delivery of aeroplanes to our flying service was 50, while during the last twelve months of the war the average deliveries were 2,700 per month. So far as aero-engines are concerned, our position in 1914 was by no means satisfactory. We depended for a large proportion of our supplies on other countries. In the Aerial Derby of 1913, of the 11 machines that started, not one had a British engine. By the end of the war, however, British aero-engines had gained the foremost place in design and manufacture, and were well up to requirements as regards supply. The total horse-power produced in the last twelve months of the war approximated to 8,000,000 of brake horse-power, a figure quite comparable with the total horse-power of the marine engine output of the country.*

Much might be written on the progress in aircraft, but the subject will be treated at length in the sectional papers. In view of the recent transatlantic flights, however, I feel that it may be opportune to make the following observations on the comparative utility of aeroplanes and airships for commercial purposes. In the case of the aeroplane, the weight per horse-power increases with the size, other things being equal. This increase, however, is met to some extent by a multiplicity of engines, though in the fusilage the increase remains.

On the other hand, with the airship the advantage increases with the size, as in all ships. The tractive effort per ton of displacement diminishes in inverse proportion to the dimensions, other things, including the speed, being the same. Thus, an airship of 750 ft. length and 60 tons displacement may require a tractive force of 5 per cent., or 3 tons, at 60 m.p.h.; while one of 1,500 ft. in length and $8 \times 60 = 480$ tons displacement,

* See Lord Weir's paper read at the Victory Meeting of the North-East Coast Institution of Engineers and Shipbuilders, July, 1919.

would only require 2¼ per cent. × 480 = 12 tons at the same speed, and would carry fuel for double the distance.

With the same proportion of weight of hull to displacement, the larger airship would stand double the wind pressure, and would weather storms of greater violence and hailstones of greater size. It would be more durable, the proportional upkeep would be less, and the proportional loss of gas considerably less. In other words, it would lose a less proportion of its buoyancy per day. It is a development in which success depends upon the project being well thought out and the job being thoroughly well done. The equipment of the air sheds with numerous electric haulage winches, and all other appliances to make egress and ingress to the sheds safe from danger and accident, must be ample and efficient.

The airship appears to have a great future for special commerce where time is a dominant factor and the demand is sufficient to justify a large airship. It has also a great field in the opening up of new countries where other means of communication are difficult. The only limitation to size will be the cost of the airship and its sheds, just as in steam vessels it is the cost of the vessels and the cost of deepening the harbours that limit the size of Atlantic liners.

Such developments generally take place slowly, otherwise failures occur—as in the case of the Great Eastern—and it may be many years before the airship is increased from the present maximum of 750 ft. to 1,500 ft. with success, but it will assuredly come. If, however, the development is subsidised or assisted by Government, incidental failures may be faced with equanimity and very rapid development accomplished.* In peace time the seaplane, aeroplane and airship will most certainly have their uses. But, except for special services of high utility, it is questionable whether they will play more than a minor part as compared with the steamship, railway and motor transport.

Electricity.—The supply and use of electricity has developed rapidly in recent years. For lighting it is the rival of gas, though each has its advantages. As a means of transmitting power over long distances it has no rival, and its efficiency is so high that when generated on a large scale and distributed over large area it is a cheap and reliable source of power for working factories, tramways, suburban railways and innumerable other purposes, including metallurgical and chemical processes. It is rapidly superseding locally generated steam-power, and is a rival to the small and moderate-sized gas and oil engines. It has made practicable the use of water-power through the generation of electricity in bulk at the natural falls, from which the power is transmitted to the consumers, sometimes at great distances.

Fifteen years ago electricity was generated chiefly by large reciprocating steam engines, direct coupled to dynamos or alternators; but of late years steam turbines have in most instances replaced them, and are now exclusively used in large generating stations, because of their smaller cost and greater economy in fuel. The size of the turbines may vary from a few thousand horse-power up to about 50,000 h.p. At the end of last year the central electric stations in the United Kingdom contained plant aggregating 2,750,000 kw., 79 per cent. of which was driven by steam turbines.

Much discussion has taken place as to the most economical size of generating stations, their number, the size of the generating units and the size of the area to be supplied. On the one hand, a comparatively small number of very large or super-stations, instead of a large number of moderate-sized stations dotted over the area, results in a small decrease in the cost of production of the electricity, because in the super-stations larger and slightly more economical engines are employed, while the larger stations permit of higher organisation and more elaborate labour-saving appliances. Further, if in the future the recovery of the by-products of coal should become a practical realisation as part of the process in the manufacture of the electric current, the larger super-stations present greater facilities than the smaller stations. On the other hand, super-stations involve the transmission of the electricity over greater distances, and consequently greater capital expenditure and cost of maintenance of mains and transmission apparatus, and greater electrical transmission losses; while the larger generating unit takes longer to overhaul or repair, and consequently a larger percentage of spare plant is necessary.

The greatest element in reducing the cost of electricity is the provision of a good load factor. In other words, the utilisation of the generating plant and mains to the greatest extent during the twenty-four hours of each day throughout the year. This is a far more important consideration than the size of the station, and it is secured to the best advantage in most cases by a widespread network of mains, supplying a diversity of consumers and users, each requiring current at different times of the day. The total load of each station being thus an average of the individual loads of a number of consumers is, in general, far less fluctuating than in the case of small generating and distributing systems, which supply principally one class of consumer, a state of affairs that exists in London, for instance, at the present time. It is true that there may be exceptional cases, such as at Kilmarnock, where a good load factor may be found in a small area, but in this case the consumers are chiefly mills, which require current for many hours daily.

There is no golden rule to secure cheap electricity. The most favourable size, locality and number of generating stations in each area can only be arrived at by a close study of the local conditions; but there is no doubt that, generally speaking, to secure cheap electricity a widespread network of mains is in most cases a very important, if not an essential, factor.

The electrification of tramways and suburban railway has been an undoubted success where the volume of traffic has justified a frequent service, and it has been remarkable that where suburban lines have been worked by frequent and fast electrical trains there has resulted a great growth of passenger traffic. The electrification of main line railways would, no doubt, result in a saving of coal; at the same time the economical success would largely depend on the broader question as to whether the volume of the traffic would suffice to pay the working expenses and provide a satisfactory return on the capital.

Municipal and company generating stations have been nearly doubled in capacity during the war to meet the demand from munition works, steel works, chemical works and for many other purposes. The provision of this increased supply was an enormous help in the production of adequate munitions. At the commencement of the war there were few steel electric furnaces in the country; at the end of last year 117 were at work, producing 20,000 tons of steel per month, consisting chiefly of high-grade ferro alloys used in munitions.

THE FUTURE.

The nations who have exerted the most influence in the war have been those who have developed to the greatest extent their resources, their manufactures and their commerce. As in the war, so in the civilisation of mankind. But, viewing the present trend of developments in harnessing water-power and using up the fuel resources of the world for the use and convenience of man, one cannot but realise that, failing new and unexpected discoveries in science, such as the harnessing of the latent molecular and atomic energy in matter, as foreshadowed by Clerk Maxwell, Kelvin, Rutherford and others, the great position of England cannot be maintained for an indefinite period. At some time more or less remote—long before the exhaustion of our coal—the population will gradually migrate to those countries where the natural sources of energy are the most abundant.

Water-Power and Coal.—The amount of available water-power in the British Isles is very small as compared with the total in other countries. According to the latest estimates the total in the British Isles is under 1,500,000 h.p., where Canada alone possesses over 20,000,000 h.p., of which over 2,000,000 h.p. have already been harnessed. In the rest of the British Empire there are upwards of 30,000,000 h.p. and in the remainder of the world at least 150,000,000 h.p., so that England herself possesses less than 1 per cent. of the water-power of the world. Further, it has been estimated that she only possesses 2¼ per cent. of the whole coal of the world. To this question I would wish to direct our attention for a few minutes.

I have said that England owes her modern greatness to the early development of her coal. Upon it she must continue to depend almost exclusively for her heat and her source of power, including that required for propelling her vast mercantile marine. Nevertheless she is using up her resources in coal much more rapidly than most other countries are consuming theirs, and long before any near approach to exhaustion is reached her richer seams will have become impoverished, and the cost of mining so much increased that, given cheap transport, it might pay her better to import coal from richer fields of almost limitless extent belonging to foreign countries, and workable at a much lower cost than her own.

Let us endeavour to arrive at some approximate estimate of the economic value of the principal sources of power. The present average value of the royalties on coal in England is about 6*d.* per ton, but to this must be added the profit derived from mining operations after paying royalties and providing for interest on the capital expended and for its redemption as wasting capital. After consultation with several leading experts in these matters I have come to the conclusion that about 1*s.* per ton represents the pre-war market value of coal in the seams in England.

It must, however, be remembered that, in addition, coal has a considerable value as a national asset, for on it depends the prosperity of the great industrial interests of the country, which contribute a large portion of the wealth and revenue. From this point of view the present value of unmined coal seems not to have been sufficiently appreciated in the past, and that in the future it should be better appraised at its true value to the nation.

This question may be viewed from another aspect by making a comparison of the cost of producing a given amount of electrical power from coal and from water-power. Assuming that 1 h.p. of electrical energy maintained for one year had a pre-war value of 5*l.*, and that it requires about 8 tons of average coal to produce it, we arrive at the price of 6*s.* 3*d.* per ton, *i.e.*, crediting the coal with half the cost. The capital required to mine 8 tons of coal a year in England is difficult to estimate, but it may be taken approximately to be 5*l.*, and the capital for plant and machinery to convert it into electricity at 10*l.*, making a total of 15*l.* In the case of water-power the average capital cost on the above basis is 40*l.*, including water rights (though in exceptionally favoured districts such lower costs are recorded).

From these figures it appears that the average capital required to produce electrical power from coal is less than one-half the amount that is required in the case of water-power. The running costs, however, in connection with water-power are much less than those in respect of coal. Another interesting consideration is that the cost of harnessing all the water-power of the world would be about 8,000,000,000*l.*, or equal to the cost of the war to England.

Dowling has estimated the total coal of the world as over 7,000,000,000,000 tons, and whether we appraise it at 1*s.* or more per ton, its present and prospective value is prodigious. For instance, at 6*s.* 3*d.* per ton it amounts to nearly one-hundred times the cost of the war to all the belligerents.

In some foreign countries the capital costs of mining are far below the figures I have taken, and as coal is transportable over long distances and, generally speaking, electricity is not so at present, therefore it seems probable that capital will in the immediate future flow in increasing quantity to mining operations in foreign countries rather than to the development of the more difficult and costly water-power schemes. When, however, capital becomes more plentiful the lower running costs of water-power will prevail, with the result that it will then become rapidly developed.

As to the possible new sources of power, I have already mentioned molecular energy, but there is another alternative which appears to merit attention.

Bore Hole.—In my address to Section G in 1904 I discussed the question of sinking a shaft to a depth of 12 miles, which is about ten times the depth of any shaft in existence. The estimated cost was 5,000,000*l.* and the time required about 85 years.

The method of cooling the air-locks to limit the barometric pressure on the miners and other precautions were described, and the project appeared feasible. One essential factor has, however, been queried by some persons: Would the rock at the great depth crush in and destroy the shaft? Subsequent to my address I wrote a letter to *Nature*, suggesting that the question might be tested experimentally. Professor Frank D. Adams, of McGill University, Montreal, acting on the suggestion, has since carried out exhaustive experiments, published in the *Journal of Geology* for February, 1912, showing that in limestone a depth of 15 miles is probably practicable, and that in granite a depth of 30 miles might be reached.

Little is at present known of the earth's interior, except by inference from a study of its surface, upturned strata, shallow shafts, the velocity of transmission of seismic disturbances, its rigidity and specific gravity, and it seems reasonable to suggest that some attempt should be made to sink a shaft as deep as may be found practicable and at some locality selected by geologists as the most likely to afford useful information.

When we consider that the estimated cost of sinking a shaft to a depth of 12 miles at present-day prices is not much more than the cost of one day of the war to Great Britain alone, the expense seems trivial as compared with the possible knowledge that might be gained by an investigation into this unexplored region of the earth. It might, indeed, prove of inestimable value to science, and also throw additional light on the internal constitution of the earth in relation to minerals of high specific gravity.

In Italy, at Lardarello, bore-holes have been sunk which discharge large volumes of high-pressure steam, which is being utilised to generate about 10,000 h.p. by turbines. At Solfatara, near Naples, a similar project is on foot to supply power to the great works in the district. It seems, indeed, probable that in volcanic regions a very large amount of power may be in the future obtained directly or indirectly by boring into the earth, and that the whole subject merits the most careful consideration.

While on the subject of obtaining power, may I digress for a few moments and describe an interesting phenomenon of a somewhat converse nature, viz., that of intense pressure produced by moderate forces closing up cavities in water.

A Committee was appointed by the Admiralty in 1916 to investigate the cause of the rapid erosion of the propellers of some of the ships doing arduous duties. This was the first time that the problem had been systematically considered. The Committee found that the erosion was due to the intense blows struck upon the blades of the propellers by the nuclei of vacuous cavities closing up against them. Though the pressure bringing the water together was only that of the atmosphere, yet it was proved that at the nucleus 20,000 atmospheres might be produced.

The phenomenon may be described as being analogous to the well-known fact that nearly all the energy of the arm that swings it is concentrated in the tag of a whip. It was shown that when water flowed into a conical tube which had been evacuated, a pressure of over 140 tons per square inch was recorded at the apex, which was capable of eroding brass, steel and in time, the hardest steel. The phenomenon may occur under some conditions in rivers and waterfalls where the velocity exceeds 50 ft. per second, and it is probably as great a source of erosion as by the washing down of boulders and pebbles. Then again, when waves beat on a rocky shore, under some conditions intense hydraulic pressures will occur, quite sufficient of themselves to crush the rock and to open out narrow fissures into caves.

Research.—The whole question of the future resources of the Empire is, I venture to think, one which demands the serious attention of all scientists. It should be attacked in a comprehensive manner, and with that insistence which has been so notable in connection with the efforts of British investigators in the past. In such a task, some people might suggest, we need encouragement and assistance from the Government of the country. Surely we have it. As many here know, a great experimental step towards the practical realisation of Solomon's House, as prefigured by Lord Bacon in the "New Atlantis," is being made by the Government at the present time. The inception, constitution and methods of procedure of the Department, which

* The literature on this subject includes an article which appeared in ENGINEERING on January 3, 1919.

was constituted in 1915, were fully described by Sir Frank Heath in his paper to the Royal Society of Arts last February, and it was there stated by Lord Crewe that, so far as he knew, this was the only country in which a Government Department of Research existed. The Italian Government are now, however, establishing a National Council for Research, and a Bill is before the French Chamber for the establishment of a National Office of Scientific, Industrial and Agricultural Research and Inventions.

Another important part of the work of the Department has been to foster and to aid financially associations of the trades for the purpose of research. Nine of these associations are already at work; eight more are approved, and will probably be at work within the next two months; and another 12 are in the earlier stage of formation. There are also signs of great increase of research by individual factories. Whether this is due to the indirect influence of the Research Department or to a change in public opinion and a more general recognition of the importance of scientific industrial research, it is difficult to say.

The possibility of the uncontrolled use on the part of a nation of the power which science has placed within its reach is so great a menace to civilisation,* that the ardent wish of all reasonable people is to possess some radical means of prevention through the establishment of some form of wide and powerful control. Has not science forged the remedy by making the world a smaller arena for the activities of civilisation, by reducing distance in terms of time? Alliances and unions, which have successfully controlled and stimulated republics of heterogeneous races during the last century, will therefore have become possible on a wider and grander scale, thus uniting all civilised nations in a great League to maintain order, security and freedom for every individual and for every State and nation liberty to devote their energies to the controlling of the great forces of Nature for the use and convenience of man, instead of applying them to the killing of each other.

Many of us remember the President's banner at the Manchester Meeting in 1915, where science is allegorically represented by a sorrowful figure covering her eyes from the sight of the guns in the foreground. This year science is represented in her more joyful mien, encouraging the arts and industries. It is to be sincerely hoped that the future will justify our present optimism.

COST OF SHIPBUILDING IN JAPAN.—The present cost of ship construction in Japan, says the British Consul-General at Kobé, is approximately 250 yen per ton for cargo steamers and 300 yen per ton for tank steamers. The cost in the United States of America, some time after the Armistice was declared, was reported at 109.57 dolls. per ton for cago steamers and 138.05 dolls. for tank steamers. In view of the higher cost obtaining in Japan, the Kawasaki Dockyard Company have been unable to accept orders coming from America. The cost of tonnage in Japan sank at one time to the figure of somewhere about 200 yen, but the prospect of increased requirements in view of reprovisioning enemy countries created a more favourable market. The present figures, which are higher than those recently ruling, are still well below the price offered by the Kokusai Kisen Kaisha (International Steamship Company) which have purchased at 350 yen. According to a well-known Japanese shipbuilding authority, some shipbuilding companies are diverting some of their efforts to the manufacture of machinery rather than maintain their whole establishment for the purpose of turning out ships. (*Il.* = about 10 yen.)

DENSITY AND TEMPERATURE.—Members of organic compounds belonging to homologous series, differing in composition by the group CH_2 (for instance, the hydrocarbons methane CH_4, ethane C_2H_6, propane C_3H_8, &c., and similarly the alcohols, acids, ethers, &c., derived from the hydrocarbons) show many striking regularities in their properties. Melting and boiling points rise with increasing molecular weight, solubility, refractive power and activity grow or diminish and so on. These regularities extend to the molecular volumes, but there is no similar relation for the densities. As a rule the density diminishes as the molecular weight increases. Thus the densities of benzene C_6H_6, toluene C_7H_8, xylene C_8H_{10} are 0·8790, 0·8707, 0·8637, and for methyl acetate, proponiate and butyrate the figures are 0·9593, 0·9383, 0·9207. But in the case of the hydrocarbons pentane, heptane, octane, the density increases with the molecular weight, viz. 0·6454, 0·6705, 0·7005, whilst in the case of the alcohols, methyl, ethyl and propyl there is no regularity at all, the densities being 0·81, 0·8065, 0·8183. The figures we have given refer to the temperature of 0 deg. C. W. Herz, of Breslau, who is studying the correlation of properties, points out in the *Zeitschrift für Elektrochemie* of May 1 last, however, that at high temperatures, near the critical points of the respective compounds, there is a regular increase of the density with increasing molecular weight, as one would be inclined to expect, and that the ratio of the densities of two members of a homologous series increases regularly with increasing temperature. At 240 deg. C. the alcohols, methyl, ethyl propyl, *e.g.*, the critical temperatures of which are 240 deg., 243 deg., 263·7 deg. C., have the densities 0·2722, 0·3825, 0·4920, and this regularity is very general, but does not hold for solids, of course.

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* For instance, it might some day be discovered how to liberate instantaneously the energy in radium, and radium contains 2,500,000 times the energy of the same weight of T.N.T.

BOARD OF TRADE EXPORT FACILITIES.

THE Government are prepared, from Tuesday next, September 9, through their Export Credits Department at 10, Basinghall-street, E.C. 2, to consider applications for advances up to 80 per cent. of the cost of the goods, plus freight and insurance, for goods sold to Finland, the Baltic Provinces (Latvia, Esthonia and Lithuania), Poland, Czecho-Slovakia, Jugo-Slavia, and the areas in Russia to which the scheme for insurance against abnormal commercial risks applies—subject to the following conditions:—

1. Documents are to be surrendered to the buyers against their acceptance of a bill in sterling drawn by the sellers for the full amount of the invoices, together with security (see the next paragraph). The Government will release the drawers from any recourse against them for the amount of the advances made.

2. The purchasers must agree to take up such documents against a deposit of currency calculated on the basis of the market exchanges, such deposit to be made with an approved bank in the country of purchase and to be held as security for the due payment of the bills.

3. When the advance is needed, the relative documents will have to be accompanied by a letter of guarantee from an approved bank of the country of purchase stating that the documents will be promptly taken up against such deposit of currency and undertaking that the amount of such currency shall always be maintained at a figure sufficient to give a margin of 15 per cent. over the value of sterling as based upon the exchanges (not upon the official exchanges, if any). All applications accompanied by a banker's guarantee of sterling payment at maturity of the bill will receive preferential consideration.

4. The department will consider proposals for a deposit of produce or securities instead of currency.

5. The advances made by the department will be a first charge upon the proceeds of the bills and securities; but, if such proceeds are less than the cost, plus freight and insurance, the loss represented by the difference will be divided between the department and the drawer of the bill in the proportion of the advance made to the cost (plus freight and insurance).

6. The credits are to outstand only for such periods as the department may determine in each case at the time of application for the advances.

7. The Government will settle from time to time the countries and goods to which the scheme relates, but advances will not be made for the export of raw materials, and preference will be given to the finance of goods where the larger part of the cost is due to manufacture in this country.

8. All applications must be passed to the department by the bankers of the sellers, whose recommendation must be attached.

9. After satisfaction of the advance the bill and securities will be handed to the seller if payment of the full amount of the bill has not been made.

10. At any time after maturity of the bill or after any default the department will be entitled to close a transaction and hand over the security held, the seller bearing his proportion, as indicated above, of any loss incurred.

11. The conditions set out above may be modified at any time or in special cases.

With the consent of Barclay's Bank, Limited, Mr. L. A. Davis, deputy foreign manager of that bank, has been appointed manager of the department.

THE LATE MR. WILLIAM ARBUCKLE MACKIE.—We regret to have to record the death, which occurred on the 3rd inst., of Mr. William Arbuckle Mackie, shipbuilder, of Glasgow. Mr. Mackie was for about twenty-one years principal of the firm of Mackie and Thomson, shipbuilders, Govan. He retired in 1909, when the site of the works was acquired by Messrs. Harland and Wolff, Limited. Messrs. Mackie and Thomson built many trawlers and other vessels of the smaller classes, and Mr. Mackie was widely known in connection with this work. He was born at Kilmarnock, and served his apprenticeship with Messrs. Charles Connell and Co., Whiteinch. He was afterwards on the drawing office staff of Messrs. Alexander Stephen and Sons, Linthouse, where he became chief draughtsman. He was a member of the Institution of Naval Architects since 1888, a member of the Institution of Mechanical Engineers since 1906, and of the Institution of Engineers and Shipbuilders in Scotland. After retiring from active shipbuilding Mr. Mackie conducted a consulting business in Glasgow. He was 70 years of age.

ON THE WEAR OF TRAMWAY RAILS.—In an article on this subject contained in the March-April issue of the *Belgian Revue Universelle des Mines*, the author states that the extent of the corrugations produced on the head of tramway rails varies with the nature, the quality and the homogeneity of the steel; the temperature at which rolling took place, the rapidity with which the rails were rolled and the pressure exerted by the rolls seem to play also a notable part, whilst the work of straightening the rail may produce corrugations of great amplitude which in their turn may influence the corrugations that occur in service. The stiffness of the track, the difference in the rail levels and the difference in the length of two rails forming the track exert also an influence on the production of corrugations. The hunting and pitching of the vehicle also come in. But the author believes that the first cause of the undulatory wear of tramway rails can be traced back to the quality of the metal used, to its lack of homogeneity and to faults in the process of rolling the rails. Other factors attributable to the track, the vehicles and their running make for the development of that class of wear.

AIR SHIPS.*

By Wing Commander T. R. CAVE-BROWNE-CAVE, C.B.E., R.A.F.

Introduction.—Airship development has depended very largely upon the work, not only of those scientific men whom we have been able to have in the Service during the war, but of the many others who have given invaluable assistance on an enormous variety of matters. The future development involves even more scientific problems, and I have framed this lecture to include, not the points of most general interest, but mainly those difficulties of greatest interest to the scientific world which we know from experience is always ready to help. The circumstances governing the variation of static equilibrium of an airship will be discussed. At the end of the paper some slides will be shown to illustrate some of the operations carried out by airships during the war.

The principal difficulty which is experienced with the use of airships for long periods, more particularly in tropical countries, is the deterioration of the fabric under the action of sunlight. This deterioration takes two forms, firstly the strength of the textile material is decreased, and secondly the gas-holding properties of the proofing material are destroyed.

The rigid airship contains a large number of gasbags formed of the lightest possible gastight material. This is usually a very light cotton cloth proofed with goldbeaters skin stuck to it by means of rubber solution. The skins are then varnished as a protection against moisture. The actual tensile strength of this fabric is only sufficient to prevent damage during the motion of the gasbags in the ship's framework.

The outer surface of the ship is formed by an outer cover of linen of much the same strength as that used for aeroplane wings. The duties which this outer cover has to perform are very important. It has to be stretched sufficiently tight to prevent any flapping or appreciable deformation during the passage of the ship through the air. It must be waterproof and also water-repellant in order to reduce the weight added to the ship by a shower of rain. A further function, and one very difficult to fulfil, is the protection that it has to afford to the internal gasbags.

The outer surface of non-rigid ships is made with a shining aluminium finish so that as much as possible of the heat and light is reflected. The rubber immediately under the surface is made to contain considerable more litharge than otherwise necessary as this material absorbs a large proportion of that light which passes the reflecting surface. A similar system is being followed with the outer covers of rigid airships, and judging by the excellent results obtained from somewhat similar methods employed on aeroplane fabric, the protection both to the fabric of the cover and to the internal bags, should be very good.

Experience with rigid outer covers is at present small, but it has been found that with non-rigid envelopes made by our latest methods of proofing, the deterioration of the outer surface becomes clearly visible before any serious loss of strength has taken place.

The envelope of a non-rigid ship is formed of layers of fabric which have to be of considerable strength in order to resist the small internal pressure necessary to maintain the rigidity of the ship. Between these layers of fabric is placed one or more layers of gas-tight rubber.

The strength of a fabric envelope can be calculated with considerable accuracy if it is assumed that the fabric is undamaged. The reduction of strength caused by a small local wound is, however, very considerable, because such a wound causes concentration of stress at the edges of the hole, and there is a tendency for the fabric to rip. This dangerous concentration of stress can be very largely avoided in a two-ply fabric if the threads of one ply are laid at 45 deg. to those of the other. The threads of the diagonal ply then form an effective means of distributing the stress, and also when tearing actually begins tend to form together into a bunch which exerts considerable concentrated resistance to the extension of the tear.

The following table shows the reduction of strength caused by a ½ in. wound out in a 6-in. strip in a direction at right angles to the direction of the stress.

Fabric.	Strength wounded. / Strength unwounded.
Single ply cotton	0·39
Single ply linen	0·52
2-ply parallel CC.	0·33
2-ply diagonal BD.	0·57
2-ply diagonal CC.	0·72
3-ply diagonal CCC.	0·68

The strength of the fabric used in the envelope of the "N.S." airships is 1,770 kilos per metre, *i.e.*, 100 lbs. per inch.

The stress in an airship envelope is very largely determined by the internal pressure which it is necessary to maintain in order to keep correct shape. The circumferential stress which this pressure produces in the fabric is, like that in an ordinary boiler shell, about twice that in the longitudinal direction. Ordinary fabric is usually of about equal strength in the warp and weft directions, and in order to resist the circumferential tension the envelope has to be made with a quite unnecessary longitudinal strength with a consequent increased weight.

It has been found possible to re-inforce an envelope

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* Lecture delivered to Engineering Section "G" British Association. *Note.*—Slides were exhibited to show the general construction of the various types of airships.

by means of flat bundles of string placed circumferentially round the envelope at suitable intervals, so that these strings contribute the difference between the circumferential and longitudinal tensions. The fabric, therefore, need only be made sufficiently strong to take the longitudinal tension. This system of re-inforcement has not at present been tried on a full size envelope but was found to give very satisfactory results when adopted on 20-ft. model envelopes which were tested to destruction.

In considering the best material for envelope re-inforcement, very careful attention had to be directed to the tensile strength of a material compared with its weight for a given length. This was found to be most conveniently represented by the length of the strand which would hang vertically down without breaking under its own weight. This was termed the breaking length of the material. Values for some usual materials are given in the table :—

Material.	Breaking length in metres.
Thread, 3-strand cotton	12,600
Thread, 3-strand flax	15,900
Thread, 3-strand hemp	12,800
Pains light rocket cord	28,600
Best Italian hemp cord	27,500
Airship cotton fabric	10,000
Aeroplane linen fabric	14,000
Envelope fabric (proofed)	4,000
Re-inforcing string tape	12,600
Aluminium 10 tons/in.	6,400
Duralumin 24 tons/in.	14,400
Mild steel 30 tons/in.	6,200
H/T steel 100 tons/in.	20,600

The gastightness of fabrics and of seams formed in them is a matter which has been very thoroughly dealt with in papers to the Advisory Committee for Aeronautics, which it is understood will be published very shortly. It may, however, be said that the amount of hydrogen which leaks out through the fabric of an airship is a matter of purely nominal importance with fabrics of the excellence now available. The matter of real importance is the passage of air through the fabric into the gas space. This air reduces the purity of the gas, and unless very large quantities of gas are consumed by the ship by discharge through the valves, it is impossible to eliminate this air sufficiently to maintain the gas purity which is necessary to give the ship her required lift.

An interesting point which has been clearly established is that the air which diffuses into the gas space tends to collect at the bottom of the envelope, more particularly in trilobe ships where the circulation of gas is less free than in circular envelopes. Samples of gas taken from within 12 in. or so of the bottom of the envelope show a hydrogen purity of some 1 per cent. lower than that in the rest of the envelope. Further the ratio of oxygen to nitrogen in this impurity shows that the air has come in by diffusion and not by mechanical leakage. This puddle of impure gas only collects while the ship is at rest in the shed, and is quickly dissipated as soon as flight is started.

Some of the chemical and physical changes which accompany the loss of gas-tightness of a rubber proofed fabric are at present very obscure. Loss of gas-tightness appears to proceed very slowly for a considerable time, and then to become very rapid, almost in the nature of a sudden collapse. In some cases the gas-tightness is actually found to increase for a short time after the fabric has been made.

The effect of the sun's radiation on the outer surface of the ship produces other important results. It raises the temperature of the gas and the air contained within the outer envelope to a point considerably above that of the surrounding air. This results in what is termed "false lift." Immediately the strength of the sun's rays decreases the super-heat begins to disappear, and the false lift of the ship is reduced. The extent of this superheat sometimes amounts to 30 deg. F. to 35 deg. F., corresponding to a loss of some 6 per cent. of the total lift of the ship. A rigid ship flying towards the sun superheats the gas in her forward compartments considerably more than that aft, and a change of trim results. Flow of air over the surface of the ship, and the circulation of air between the outer cover and the gasbags of a rigid ship tend to reduce superheat.

Changes of temperature in which the gas and air readings remain equal to each other, do not involve change of lift unless the expansion of the gas is sufficient to involve discharge of gas from the ship. If the ship becomes light and is allowed to rise higher than is otherwise necessary, much gas may be discharged. If weight can be taken into the ship, so that she does not rise, the loss of gas may be avoided, and this may be of considerable value during the next night when the ship has cooled down, and possibly absorbed moisture.

There are several methods of taking weight into the ship. One is to condense the exhaust, and by this method a weight considerably in excess of the weight of fuel burnt can theoretically be obtained. It is found that the exhaust gas from a 260 h.p. engine can be cooled to within 10 deg. F. of the atmosphere temperature in a cooler weighing about 120 lbs. This would, in a rigid airship, take the place of a silencer weighing some 60 lbs., and the added weight is not, therefore, very great. The form of cooler used resembles a honeycomb radiator with 1-in. tubes through which the air passes, the exhaust passing through the space around the tubes. There is, however, difficulty in this condensation, because the cooling surfaces rapidly become fouled and conductivity very greatly reduced.

An alternative is to draw water direct from the sea, either by a propeller-driven pump contained in a body towed by the ship and discharging water up a hose, or by filling a specially shaped fabric drogue and hoisting that weight of water into the ship by means of an ordinary winch. Both these operations involve considerable difficulty in handling the ship, more particularly because at the time she wants water she is seriously out of trim.

A further and possibly more promising alternative is to burn the hydrogen which would otherwise have to be discharged, and to condense the water of combustion. This is considerably easier than condensing the exhaust gas, because there will be no fouling of the cooling surfaces.

Experiments have been made on the use of hydrogen as fuel, and considerable success has been achieved. It is found that with very simple gear hydrogen can be burnt in an ordinary airship engine. When burning hydrogen alone it is not possible to develop more than 25 per cent. or 30 per cent. of the power which the same engine would give on petrol. If greater power is attempted serious detonation in the cylinder results. By providing a hydrogen-air mixing valve in parallel with the petrol carburettor it is possible to obtain any fraction up to the full power of the engine by suitably proportioning the relative amounts of hydrogen and petrol mixture burnt. The proportion of hydrogen which it is possible to burn depends upon the proportion of full power which is required from the engine. Under all ordinary circumstances a very considerable saving in fuel can be achieved.

The risk of fire in airships has considerably reduced the warlike operations which these aircraft have been allowed to undertake. For commercial purposes some small risk of fire also exists. The proportion of this risk which is due to the presence of hydrogen is, in the case of commercial craft especially, considerably smaller than is generally believed. The engines and other possible sources of ignition are carefully arranged at a considerable distance away from any point at which gas can possibly be discharged, and the speed with which gas when liberated rises clear of the ship, is such that only a very serious fire in one of the engine cars could possibly be communicated to the gas.

Although during the war British airships flew nearly 3,000,000 miles the only ships which were destroyed by fire were, one, the first, "S.S." ship which ran into some telegraph wires and caught fire, the crew escaping; two, a coastal ship which landed on the water and caught fire for an unknown reason, and lastly, an "S.S." ship which landed on top of another in a thick fog.

The petrol system is a source of danger which is probably at least as great as that due to the gas. Large quantities of petrol are stored in the keel of a rigid airship, and the petrol system is necessarily connected to the engine cars. The possibility of transmitting fire to the envelope of the ship would be very greatly reduced if paraffin or an equally safe fuel could be employed. The added safety which would be derived from a less inflammable fuel would probably justify some increase in the weight of machinery necessary to develop the required horse-power.

It may here be well to draw attention to the relative importance of the weight of the engine and the weight of the fuel consumed. This relation is very different from that which obtains in an aeroplane where the length of flight is considerably less. An aeroplane engine weighs some 3 lb. per horse-power, and may be expected to burn a weight of fuel equal to its own in six or hours eight hours. The machinery of an airship will, of course, during an ordinary passage run for many times this duration of flight, and further a large proportion of the flight will be carried out at less than the full power of the engines. A "North Sea" airship carried out one patrol of 101 hours, while the flight of R. 34 to New York involved a continuous flight of 106 hours. From this it will be clear that an airship engine must be one of the very highest fuel economy, not only at full power, but also at fractions down to 25 per cent. of the maximum power. The increase of weight of engine justified by a small improvement in fuel economy is, therefore, considerable.

The use of steam for airship propulsion has been considered, and although the convenience of such a system is very great and the weight of machinery, including boiler and condenser, is not seriously in excess of the corresponding petrol engine, there appears at present no likelihood of reducing the fuel consumption to much less than 1 lb. per horse-power hour. This is clearly prohibitive when compared with the consumption by a petrol engine of less than 0·5 lb. per horse-power hour.

In addition to the requirement of high fuel economy, it is of the greatest importance that an airship engine should be able to run for very long periods without risk of breakdown. A further point is that the engine should be arranged in such a way that all its parts which are liable to failure during running, are made easily accessible, so that a repair can be carried out in the air. This is a very important difference from the aeroplane engine, which is normally inaccessible during flight. An airship engine can be stopped during flight, and must be regarded as at least as easily accessible as that of a motor-boat. The space round it is generally at least as ample, and it is only in exceptional circumstances that the motion of the ship will in any way interfere with the execution of repairs. Defective magnetos have frequently been replaced by others of a different type and the new ones correctly timed. One repair which involved the removal and replacement of one complete cylinder of a two-engined ship, was successfully carried out, and the engine used without trouble for the remainder of the flight. A satisfactory airship engine must, therefore, be one in which repairs, even of this magnitude, can be effected as easily and with as little delay as possible.

Airship Propellers.—The variation of speed of an airship renders the design of her propellers one of very considerable difficulty. She may be required to run on one engine developing its full power and giving the ship a very low speed, or on all her five engines giving her full speed. Under these circumstances the efficiency of her propellers must necessarily be low in some conditions. A satisfactory means of varying the pitch of the propeller should, therefore, lead to a very considerable gain in the efficiency of the ship as a whole. A propeller in which the alteration of the blade angle is sufficient to give reverse thrust would be very convenient, and avoid the reverse gear-box now required.

One of the advantages which an airship possesses over an aeroplane is that her greater range will enable her to avoid atmospheric disturbances, and also to take more advantage of any depression which can be approached in such a way as to obtain a favouring wind. Meteorological information can now be obtained from a fairly considerable number of points, but prediction is rendered considerably easier if it is possible to read the barometer at a point on the ground below the ship herself. A barometer reading taken in the ship is, of course, useless unless the height of the ship can be determined by means other than barometric pressure. Instances have occurred in which the barometer has changed so greatly during an airship's patrol, that the ship struck the water during the night when her aneroid registered a height of 300 ft. When crossing an unknown country it is also desirable to determine the height above the ground, independent of the barometer and height above sea-level. To determine this height above the sea, it has been suggested that the report of a rifle discharged in the ship and reflected from the surface of the sea should be timed. A special form of stop-watch, which was used for gunnery research during the war, makes it possible to measure the interval between two similar sounds with an accuracy of within $\frac{1}{10}$ second. Up to the present the method has not been found very satisfactory, on account of the difficulty of hearing the reflected report if the ship is not stopped, or her speed seriously reduced. It is, however, possible that in an emergency this device could be used with success by stopping or slowing down the ship. This is, of course, a serious disadvantage to the method, and something better is required.

The generation of hydrogen is probably the greatest difficulty in extending the use of airships to more or less undeveloped countries. Hydrogen at present is manufactured for airship purposes mainly from coke. Some method of manufacturing hydrogen from wood or other vegetable matter would probably prove of very great value in allowing airships to work in those countries in which they have their greatest advantage over other possible forms of transport.

The use of helium has been considered, and much experimental work has been done on the extraction of this gas from the natural gases obtained from wells in Canada and America. The price of this gas, when made by present methods or by any system which appears probable in the immediate future, is, however, almost prohibitive, and failing a really remarkable discovery such as the possibility of getting hydrogen to degrade into helium, there does not appear much possibility of reducing the price to a commercial possibility.

The calculation of the stresses produced in the hull structure of a rigid airship under the many different conditions encountered, is one of considerable complexity, and one which cannot come within the limits of this lecture. The most interesting members of the structure may be regarded as long struts some 16 ft. long, designed to fail, when the ends are supported freely, under an end load of some 8,000 lb., or a distributed load of some 2,000 lb., *i.e.*, 120 lb. per foot. The construction of such a girder has involved several very interesting, though probably not novel, principles. The bracing pieces which have to be made of an easily stamped section, are formed so that their thin edges come in the neutral axis of the piece, and are, therefore, little exposed to secondary bending. The end of the bracing piece is carefully shaped so that the loading is as little eccentric as possible. Bracing pieces are arranged in pairs, and are riveted together where they cross. The piece in compression can then derive support from its fellow, which must at that time be in tension.

An interesting manner of assessing the relative merits of various types of strut is to consider how far the construction allows the material to develop its full yield stress. If a form of construction is such that the crippling load divided by the area of cross section of the strut approximates closely to the yield stress of the material, the form of construction must be considered very good.

The advantage to be gained, from a commercial point of view, by using a large ship is clear from the following consideration. For ships covering the same range at the same speed and having similar shape, the displacement varies as the cube of the linear dimensions (l^3), the weight of hull, fabric, &c., as l^3, the resistance, and, therefore, the weight of machinery and fuel as l^3

$$\therefore \quad \underset{K_1 l^3}{\text{gross lift}} = \underset{K_2 l^3}{\text{wt. of hull, \&c.}} + \underset{K_3 l^3}{\text{wt. of machinery}}$$

$$\text{Freight fuel consumed} = K_4 l^3.$$

$$\text{Hence} \quad \frac{\text{freight}}{\text{fuel}} = \frac{K_1 l^3 - K_2 l^3 - K_3 l^3}{K_4 l^3},$$

a function which clearly increases with the size of the ship.

It is, therefore, interesting to consider what limits the size of rigid and non-rigid ships of the types at present in view.

Increase of length of a rigid of given cross section appears to call for no increase in the strength of her hull, provided the load is properly distributed. No serious restriction to the length of rigids is, therefore, in view. The most dangerous stresses are produced in the main transverse members of rigids by unequal

inflation of the gasbags on either side of a bulkhead. The bulkhead is formed of wires lying in the transverse plane and attached to the joints of the main transverses. Difference of pressure in adjacent bags, therefore, induces great tension in these wires, and hence compression in the transverse frame. The possible head of gas produced by the total deflation of one bag increases with the ship's diameter, and so does the span of the wires. In a ship of large cross section, therefore, the compression in the transverse frames becomes very serious.

The non-rigid airship is not, as at present designed, divided into compartments by diaphragms capable of resisting a difference of pressure in the gas on either side. If the ship takes up a very steep pitch the internal pressure at the upper end of the ship will be seriously increased if the pressure at the lower end is still to be maintained above atmospheric. This accumulation of pressure at the upper end of the ship while pitching may prove a serious difficulty in a really large non-rigid, but it is probable that by the employment of a circular section and fabric re-inforced in the manner already referred to sizes considerably greater than any we have built at present can be achieved. The development of a large non-rigid offers—at any rate in the author's opinion—very great promise of advantage, because the ratio of disposable lift (fuel and freight) to the total displacement of the ship is so good. A non-rigid of 500,000 cub. ft. capacity, i.e. carrying a useful load of 7½ tons, will have about the same value (50 per cent.) for this ratio as a rigid ship of four times the capacity (2,000,000 cub. ft.).

The slides which follow illustrate various operations carried out by airships during the war. The last one, which shows the mooring of a rigid airship to a mast, is of extraordinary importance. The difficulty of handling a large airship is very greatly magnified in the opinion of most people. The only serious difficulty lies in getting the ship into her shed when a wind is blowing across the entrance. Bringing an airship to the mast, where she is always head to wind and the air is not even disturbed by the presence of a shed, is easy. A 60-ton airship lands in equilibrium so that the upward force the landing party exerts is nil. Compare this with even a 20-ton aeroplane touching the ground at 50 m.p.h., and running a quarter of a mile, at the end of which it is pressing on the surface of the aerodrome with its full weight of 20 tons.

The airship shown in this slide has remained at her mast for three weeks in charge of watches, each consisting of 1 N.C.O. and 5 men. She experienced winds of 35 m.p.h., with gusts up to 43 m.p.h., very heavy rain and bright sunshine, also several thunderstorms, including the very violent one of July 17, which passed over the ship at 2 a.m. At times the whole ship appeared to be aglow, and it was easily possible to read the instruments in the keel by the light of the discharges.

The ability to land and be safely secured in bad weather very greatly reduces the number of days which must be regarded as too bad for flying.

That the airship, both rigid and non-rigid, is a valuable field of investigation which will justify development, both for warlike and commercial purposes, few people who know anything of the details have any doubt. Those who know much about airships are more hopeful than those who know little. The greatest airship enthusiasts are, perhaps, those who know the achievements and the troubles of both airships and aeroplanes.

COAL TRANSPORT REORGANISATION SCHEME.—With a view to assisting in the restoration of normal conditions it has been decided, says *The Board of Trade Journal*, that the restrictions imposed on the transport of coal by rail under the Coal Transport Reorganisation Scheme should be suspended as from September 1 until further notice. In order to give effect to this decision a general permit has been issued, and it will not be necessary until further notice to apply for permits in individual cases after the above date. It is to be observed that this decision does not affect the instructions at present in force to suppliers of coal as to the maintenance of supplies to their existing customers.

GAS FURNACE TEMPERATURE RECORDER.—A device, the "Falbro" temperature controller, for controlling temperatures in gas furnaces, ovens, lead pots and other apparatus using gas fuel, has been placed upon the market by the Wilbride Company, Norwood, Pa., and is illustrated in *The Iron Age*. It is operated by air pressure and consists essentially of the controlling instrument of an automatically-operated valve for gas. The controlling mechanism is made up essentially of a galvanometer and an air motor with clamping mechanism for holding a plate on the galvanometer pointer at intervals of 4 seconds, when the air is forced through an opening in the plate, thereby causing the valve to operate the gas and air valves to regulate combustion. The position of the air and gas valves is determined by the position of the galvanometer pointer. The needle of the galvanometer, when reaching a point higher or lower than the temperature that has been set, releases the air which operates the valves either to reduce or increase the supply of fuel. In order that the instrument may be set to any desired temperature within the range of the scale, an index pointer is provided. A thermocouple placed in the furnace to be controlled is connected with the galvanometer. By this method, temperatures up to 3,000 deg. F. can be controlled; but for higher temperatures the radiation system is necessary. It is stated that the control does not vary more than 1 per cent. of the range scale. A multiple control, it is stated, can also be adapted for automatically regulating a furnace having more than one burner.

CATALOGUES.

Metals.—The Electric Alloy Company, Morristown, New Jersey, U.S.A., send leaflet catalogues describing the properties of their monel metal, and of their magneto spark point nickel.

Motor Starters.—The British Westinghouse Company, Limited, send a catalogue of direct-current motor-starters from ¼ h.p. to 75 h.p. These include open, slot cover, enclosed ventilated, and weather-proof types—the two latter with slow motion gear when required.

Machine Tools.—A list of new machine tools ready for delivery and a fairly long list of second-hand ones comes from Messrs. Lee and Hunt, Limited, Nottingham. These include the medium sizes of nearly all the machines used in general engineering shops.

Electric Conduits.—A priced list of conduits and fittings (sockets, bends, boxes) comes from the Sun Electrical Company, Limited, 120 Charing Cross-road, W.C. 2. The items are sufficiently illustrated to identify the form. A household electric ironer is also shown.

Electric Fuses.—A series of fuses made by Messrs. Siemens Brothers Dynamo Works, Limited, 38, Upper Thames-street, E.C. 4, in the form of cartridges inserted into the terminals box, are made for currents of 2 amperes to 160 amperes and pressures of 250 volts, 500 volts and 750 volts.

Small Fans.—The General Electric Company, Limited, 67, Queen Victoria-street, E.C. 4, has issued a special catalogue of small fans with electric drive. These are for placing on a table or fixing to walls, ceilings, windows, &c., and are complete with motor and fixing brackets. There is an ample variety of patterns and sizes.

Aerial Ropeways.—The system of transport on aerial ropeways can be erected in many awkward places cheaply and at short notice. It has great flexibility and quick working power. The system is well worked out by the Aerial Ropeway Transporters, Limited, Craven House, Kingsway, W.C. 2., who have issued a catalogue giving full information and several illustrations of complete sets at work. Loads of 1 to 5 tons are carried.

Commercial Motor Vehicles.—Messrs. John I. Thornycroft and Co., Limited, Basingstoke, and 10, Grosvenor-place, S.W. 1, have issued a catalogue illustrating a series of motor lorries, vans, drays, water-carts, &c., and containing a most interesting and fully illustrated description of their works and methods. It is intended to interest users of the vehicles, and should give them confidence in the value of first-rate engineering work.

Oil Purifier.—The purification of oil, and especially of crank-case oil in engines burning oil fuel is fully discussed in a catalogue received from the De Laval Separator Company, U.S.A., whose agents in this country are Chadburn (Ship) Telegraph Company, Ltd., Liverpool. Either a continuous purification of the oil circulating in the engine or treatment by complete refils may be carried out. We described this purifier on page 238 *ante*.

Shaft Couplings.—Two shaft couplings are shown in a catalogue from Electro Metals, Limited, 56, Kingsway, W.C. 2, and Stoke-on-Trent. The reversing type consists of two discs with slotted faces (like the teeth on a nearly flat bevel wheel) facing each other. A spiral spring connects these two faces and gives a flexible drive which damps and stores up the energy of shock. The non-reversing type connects projections on two discs by a leather belt laced through them, and allowing an appreciable amount of flexibility to the drive. Both are flexible in the radial direction; enough to allow for imperfect alignment of the shafts. A full range of sizes is made up to 18-in. diameter shafts for the first, and 12-in. diameters for the second.

Export Trade.—The engineering export trade to India, China, Japan and the East generally is the subject of an interesting and useful pamphlet by Mr. A. T. Stewart, Mansion House Chambers, Queen Victoria-street, E.C. 4, who has made a business of the work of placing exporters in touch with the needs and peculiarities of these foreign markets. Such a pamphlet can only consist of general advice, and a little judicious criticism, but this is evidently based on first-hand knowledge of the localities. Mr. Stewart's two main principles are: first, that he works only for British producers; and second, that he puts those producers into direct touch with their foreign customers. The second principle apparently brings him into conflict with other firms who export goods and keep the producer and buyer unacquainted with each other.

National Factories.—The Liverpool Munitions of War Committee has issued an elaborate report on the work and administration of six national shell factories or other works in the locality. 2,798 females and 1,237 males were employed. 270,000*l.* capital expenditure was incurred, and the assets, under this head, are estimated to realise 50,000*l.* The "standard value" of the output is given at 6,598,000*l.*, which is presumably the "price" estimated by the Ministry costing department. The "total cost" was less than this standard value by 827,000*l.*, which is stated as a surplus. Over half of this surplus is to the credit of the forgings shop, which employed one-fifth of the labour, and produced over one-fourth of the value. As there is no account of payments for material, labour, &c., it is not safe to attach any definite meaning to the figures. The real importance of the report is that it shows that the local people did a great deal of useful work under every disadvantage and in the best spirit.

Ore-Crushing Machines.—Some crushing machines of the monster type are the subject of a catalogue issued by Hadfields, Limited, Sheffield. One enclosed type will take ironstone in blocks up to 1½ tons, and crush them into pieces 6 in. to 8 in. at the rate of 150 tons per hour; this breaker weighs 90 tons, requires up to 200 h.p. for driving, and has water-cooled bearings. Another more open in construction, will do similar work at the rate of 100 tons per hour. A third, made in several sizes of opening, will crush about 75 tons of limestone per hour. A fourth type is called a "secondary" crusher; it takes ore or stone from the first series and reduces the pieces to 2½ in. or less, and is made in several sizes of large capacity. In these machines the jaws, cheeks, or other crushing faces are made of manganese steel, and the frames of toughened cast steel. It would appear that about 1½ h.p. to 2 h.p. will break one ton per hour. The machines are typical of the finest heavy British engineering work of ample strength for the exceptional duty for which they are intended.

Fixed Steam Engines.—The steam engine seems to have no disposition to retire to the museum. In fact our present problems of cost of coal and its effect on cost of power will involve many factory owners in careful reconsideration of any ideas they may have harboured of dismissing this old and faithful servant. In that case they will do well to give careful attention to a catalogue just issued by Messrs. Marshall, Sons and Co., Limited, Gainsborough. It is not so long ago that a good steam engine required 5 lb. of coal per horse power per hour; but now 1½ lb. will produce the same work. If we described, even briefly, the improvements which have caused this change it might be thought that a highly complicated machine had been evolved; but what really has resulted is a simpler, and a very simple, machine. Every improvement in foundry, machine tools, packing and other auxiliaries, every advance of workmanship and science is promptly appropriated by the steam engine which advances perhaps more than any other machine while preserving its first settled form as "the horizontal." It is not easy to dispute its claim to be the most reliable of all machines, and with that goes its power of taking heavy overloads safely and underloads economically. There may be works refuse to burn, or cheap inferior coal, or best steam coal, or plenty of cheap water, or the space available long and narrow or short and broad—it adapts itself to nearly all sorts of local conditions. The catalogue shows four classes of engines, fourteen sizes in each class, ranging from 13 h.p. to over 900 h.p. Really all the same simple strong form, with as much modern improvement as will be most profitable in given local circumstances. The adaptation is no great trouble to the maker of the engine and of immense advantage to the user. The descriptive part of the catalogue is in clear easy language. There are some fine illustrations of the engines at work driving mills, ironworks, engineering plant, pumping stations, and electricity generating machines.

War Record.—A book issued by Sir W. G. Armstrong Whitworth and Co., Limited, from their commercial office, 8, Great George-street, S.W. 1, gives an account of the war work executed by the firm. War vessels, from battleships to submarines, merchant ships, guns, armour-plate, land guns with carriages and mountings, torpedo tubes, airships and planes, tanks, cross-channel ferry for carrying trains, ice-breaker ferries for far northern waters, locomotives, bridges, cranes, and, in addition, over 70,000,000 shells, fuses and projectile parts—all these come into the record. The work included much new design as well as manufacture. Any attempt to summarise the products into totals of weight, horse-power or value, would only be misleading; indeed, the 53 pages of letterpress and 20 illustrations that make up this book are only a summary. The firm was called upon by the Government from the first days of the war, and later supplied the design, equipment and management for national factories to produce shell bodies. The enormous mass of production may be easiest to understand, but the varied character of it is even more remarkable; it is more like the produce of a nation than of a firm. Before the Ministry of Munitions was established and for long afterwards, the supply of munitions was prepared by this firm, and a comparatively few others of similar organisation; and the national shell factories were themselves the product of these firms. Before the war the Army supply of guns and ammunition had been reserved to Woolwich and the Royal small arms factories, but the Admiralty had continued to employ private firms. In consequence, the Navy obtained an immediate expansion of production, while the Army had to wait for months before the plant and tools of production could be created to supply a full measure. In the meantime the main burden was borne by the private firms, who made substantial deliveries for the Army even in 1914—and if these were inadequate, they were all the more precious as an addition to what the State pre-war policy had provided for. This record, like others of its kind, is entirely free from any taint of boastfulness. The writers have tried to put their reports in the form of a summary of figures with no more than slight connecting thread of explanation.

AMERICAN SHIPMENTS OF IRON BILLETS.—We read in *The Iron Age*, under date of August 19, that a report on overseas traffic issued by the Railroad Administration, indicates that all billets accumulated at the Port of New York for British ports have been loaded. Cable advices have been received to load all billets awaiting shipment to France. The French have 17 steamers at New York. One steamer carrying pig-iron and cotton cleared from Savannah for Liverpool. Another is loading pig-iron there for Rotterdam. The traffic report from the Western region announces that it is planned to build a large iron and steel plant at Los Angeles, to cost about 5,000,000 dols.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACT OF 1907.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, &c., of the Communicators are given in italics.

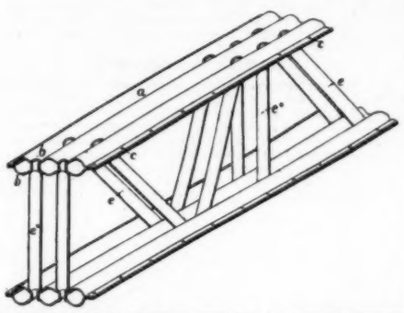
Copies of Specifications may be obtained at the Patent Office, Sales Branch, 25, Southampton Buildings, Chancery-lane, W.C., at the uniform price of 6d.

The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Act.

AERONAUTICS.

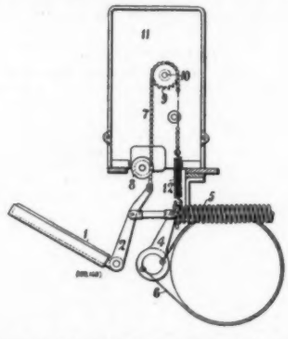
129,234. D. J. Mooney, Westminster, London, and E. E. Brown, Westminster, London. Longerons. (14 *Figs.*) March 11, 1919.—This invention relates to longerons constructed of thin metal, wherein the upper and lower parts or flanges consist of hollow corrugated members joined together by tubes or tube-like webs. The drawing is a perspective view



of a spar in which the flanges *a* consist of two corrugated metal strips *b* riveted at the flat parts *c* and connected together by slant tubes *e* and upright tubes *e** which form a lattice web. The tubes with the ferrule form a support between the corrugations *b* which are considerably stiffened thereby. (*Accepted July* 16, 1919.)

ELECTRICAL APPARATUS.

129,103. P. A. H. Mossay, Westminster, London, and Mossay and Co., Limited, Westminster, London. Controlling Electrically Propelled Vehicles. (3 *Figs.*) July 2, 1918.—This invention relates to controlling means for electrically propelled railway platform trucks. According to the present invention, the brake and speed controller are normally held by springs in the "braking" and "off" positions respectively and have operative connections with a pedal common to the two, the connections being such that when the pedal is operated to start the vehicle, the brake is released before the speed controller is brought into operation. A pedal 1 is carried by a bell crank



lever 2, connected to a band brake lever 4. A spring 5 tends to hold the brake lever with the brake band 6 on. A chain 7 is also connected to the bell crank lever 2 and passes a jockey-pulley 8 and thence around a sprocket 9 on the end of the spindle 10 of an electric controller 11. The end of the chain 7 is connected to a spring 12. The arrangement is such that, when the pedal 1 is depressed, the brake band 6 is first released and then, after a certain period of lost motion, the controller spindle 10 is rotated. If the pedal 1 be released the springs 12 and 5 return the controller to the dead position and apply the brake. (*Accepted July* 16, 1919.)

GAS ENGINES, PRODUCERS, HOLDERS, &c.

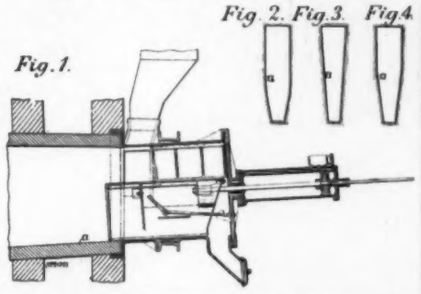
129,193. W. E. Burgess, Aberbeeg. Piston Rings. (7 *Figs.*) November 11, 1918.—This invention relates to piston rings in which two piston rings whose inner and outer peripheries are eccentric to one another with a split in the narrow part, are placed face to face, with the narrow part of the one against the wide part of the other. According to this invention, in a piston ring of the type referred to, there are provided upon the uncovered portions of the adjacent faces of the ring, projections which are adapted to lie closely against the periphery of the co-operating ring, and are of a height corresponding to its axial thickness. The complete piston rings consists of two exactly similar rings A, whose inner and outer edges are eccentric to one another, the gap A4 being, as usual, in the narrow part. Two such rings placed face to face with their outer peripheries in register and their gaps diametrically opposite one another leave crescent-shaped portions of their adjacent faces exposed. Upon those faces are formed projections A^5 of similar form, and of a height equal to the axially-measured thickness of the ring. The outer side of this projection is adapted to lie closely around the inner periphery of the co-operating ring when the two are placed together and thus to close the gap A^4 and prevent leakage in the

radial direction of the gap inwardly. To prevent relative rotation of the two rings, the gap A^4 is made sufficiently wide to receive a radially disposed extension A^6 of the crescent-shaped projection A^5. (*Accepted July* 16, 1919.)

129,139. J. West, Southport, and W. Wild, Blackpool. Retorts. (4 *Figs.*) July 17, 1918.—This invention relates to horizontal and inclined retorts for use in the destructive distillation of coal of the type in which the feed is effected by a plunger or plungers which force forward the mass of the material in the retort. The invention consists in making the retort with its sides tapering towards one another as they approach the base of the retort. The retort *a* may be of substantially wedge-shape in cross section, with its sides tapering (but preferably curved) to a short base as in Fig. 2. Or it may be said to resemble the elevation of a crucible. The sides may taper over their full depth as in Fig. 3 or for a part only of their depth, the remaining parts being parallel to one another as in Fig. 4. The retorts may or may not be tapered in their length. With the arrange-

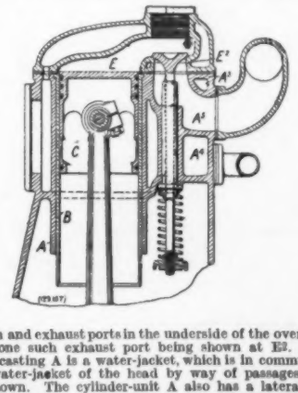
Fig. 2. Fig. 3. Fig. 4.

Fig. 1.



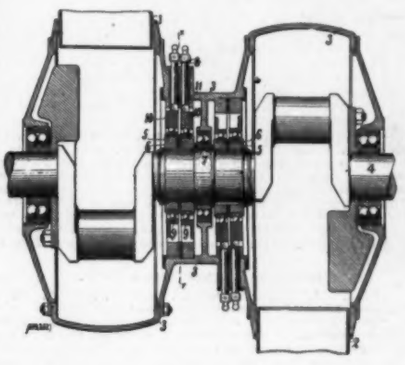
ment before described, not only is the weight of the charge distributed more evenly over the surface of the retort, but by reason of the reduced thickness of the coal in the base of the retort, the heat penetrates and completely carbonises such coal very readily, and so gives it greater power to resist buckling during propulsion and at the same time reduces the friction between the charge and the retort surface. The shape of the retort, as before described, is specially advantageous in that its maximum width being at the top, admits of a wider opening for the coal feed and a freer exit for the gas evolved from the coal. Further, the heating of the retort can be more effectively performed, as the shape of the sides will permit of a greater heat transference by conduction than with retorts having vertical sides. (*Accepted July* 16, 1919.)

129,157. C. K. Edwards, Chingford, London, and The Associated Equipment Co., Limited, Westminster, London. Cylinder-Heads. (1 *Fig.*) August 14, 1918.—This invention relates to internal-combustion engine cylinders of the type constructed with a separately attached head having a projecting portion extending beyond the cylinder, which portion contains one or more of the valve seatings and an interior chamber, one for each cylinder, which extends from the projecting portion to the cylinder, and ports constituting upwardly-directed valve-seatings. According to the present invention, an internal combustion engine-cylinder of the type described is characterised by the surface or surfaces whereby the head makes joint with the cylinder being a plane surface or all in one plane and by the whole of the head unit lying on that side of this plane which is remote from the cylinder. A cylinder-casting A has a liner B wherein a piston C works in the usual manner. The cylinder-unit A carries on its upper end a head unit E having an interior chamber in communication with the interior of the cylinder. One side of the head E projects laterally over the part of the cylinder-block A containing the cylinders, and is provided with



admission and exhaust ports in the underside of the over-hanging portion, one such exhaust port being shown at E^2. Integral with the casting A is a water-jacket, which is in communication with a water-jacket of the head by way of passages whereof one is shown. The cylinder-unit A also has a lateral portion A^5 which extends as far as does the overhanging portion of E. Ducts A^4 and A^5 are provided in this lateral portion A^5 for the admission and exhaust, respectively, of the gases, the upper ends of these ducts being situated immediately below the under side of the over-hanging portion of E at the juncture of the head with the cylinder unit. Vertical admission and exhaust ports are provided in the underside of the overhanging portion of E of the cylinder head, one of each for each cylinder, an exhaust port being shown at E^2. The lower end of this port registers with the upper end of the exhaust passage A^5, and, similarly, the lower end of the inlet port, also provided in the underside of the overhanging portion of E, registers with the upper end of the admission duct A^4. As clearly shown, all the surfaces hereby the head makes joint with the cylinder are in one plane and the whole of the head unit E lies on that side of this plane remote from the cylinder. (*Accepted July* 16, 1919.)

129,352. The Daimler Company, Limited, Coventry, A. E. Berriman, Coventry, and J. Dixon, Coventry. Internal Combustion Engines. (2 *Figs.*) October 29, 1917.—This invention refers to means for operating the valves of internal combustion engines, and is applicable to engines of the radial type, in which the cylinders are arranged in two or more planes. According to the present invention, in engines of radial type and in which the axes of the cylinders are arranged in two or more parallel planes extending transversely of the axis of the crank shaft, cam mechanism for operating the valve tappets are located between the planes of cylinders, the cam mechanisms so located being operated by eccentrics on the crank shaft, and with the cam mechanisms thus situated the operation of the valve tappets for all the cylinders becomes equally easy. A portion of the cylinder of one of the planes of cylinders is indicated at 1, and a portion of one of the cylinders in the other plane is indicated at 2, 3 being the crank case. The crank shaft



4 between the banks of cylinders has fixed upon it, for each set of radial cylinders, two eccentrics 5, 6, the crank shaft having a central bearing 7 carried from the crank case, although in some cases this central bearing might be omitted. In view of the fact that the valve-operating mechanism for one bank of cylinders corresponds to the operating mechanism of the valves of the other bank of cylinders, it will be sufficient to deal with the valve mechanism for the bank of cylinders marked 1. Two of the valve tappets for operating the inlet and exhaust valves are shown at 8, the inlet and exhaust valve tappets being arranged radially, two to operate the inlet and exhaust valves for each cylinder. Riding on each eccentric 5 and 6 is an annular cam 9 formed with peripheral projections which abut successively against the extremities of the tappets 8 as the eccentrics 5, 6 revolve, the motions of the annular cam 9 being controlled by a stationary gear ring 11 carried from the crank case 3 and having internal teeth engaging eccentrically with external teeth on the annular cam 9. (*Accepted July* 23, 1919.)

129,432. J. Marr, Sheffield, W. Colquhoun, Sheffield, and The Coke Oven Construction Company, Limited, Sheffield. Coke Ovens. (2 *Figs.*) July 9, 1918.—This invention relates to coke ovens of the horizontal flue type fed by vertical air-flues from main horizontal air-flues, and its object is to provide an improved arrangement of flues which will allow of the wall containing the vertical flues to be reduced in thickness and the cost of construction of the oven to be consequently reduced. A coke oven, according to the present invention, comprises the combination with the vertical air-supplying flues J

Fig. 1.

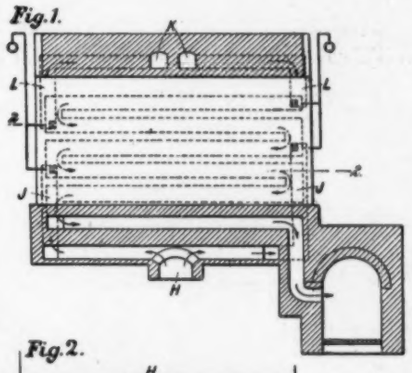
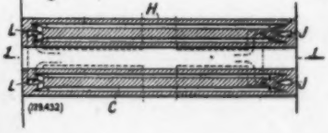


Fig. 2.

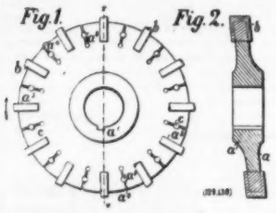


at both ends of the horizontal heating flues C fed from one or more main air-flues H at the bottom of the oven, of a second similar set of vertical air-supplying flues L fed from one or more main air-flues K at the top of the oven, the arrangement being such that the first set of flues extend approximately only half-way up the oven, and the second set approximately half-way down the same, whereby the cross-sectional area of the said flues can be decreased, for the purpose of enabling the thickness of the middle walls in which the vertical air-flues are contained to be decreased. The upper or lower vertical air-flues at one end of the improved

oven supply only approximately one quarter of the entire quantity of air for combustion as compared with approximately one half in the known type referred to above. (*Accepted July* 23, 1919.)

MACHINE AND OTHER TOOLS, SHAFTING, &c.

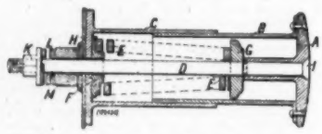
129,138. Vickers, Limited, Westminster, London, R. J. A. Pearson, Erith, and C. R. Matthews, Erith. Milling Cutters. (3 *Figs.*) July 17, 1918.—This invention relates to milling cutters of the inserted-blade type. According to the present invention, the blades are mounted in the periphery of an inclined plate formed integral with a boss or annulus having its end faces disposed at right angles to the axis of rotation. *a* is the inclined plate formed integral with the boss a^1, which is provided with a keyway for engaging a key or feather on the milling machine arbor or spindle; *b*,*b* are the blades. The peri-



phery of the inclined plate *a* is slotted at a^3 for the insertion of the blades *b* and slitted and drilled at a^4, a^5 respectively, to receive the taper pins *c* in the usual manner. The transverse peripheral slots a^3 are spaced equally around the inclined plate *a* and they are arranged at right angles to the oblique faces thereof. With this arrangement, each unit will mill a surface almost double the width of the inserted blades *b* by reason of the inclined plate, and any number of units may be assembled together to form any desired width of milling cutter. (*Accepted July* 17, 1919.)

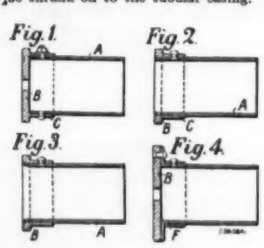
RAILWAYS AND TRAMWAYS.

129,434. J. Mitchell, Putney, London, and A. B. C. Coupler, Limited, Westminster, London. Buffers. (5 *Figs.*) July 9, 1918.—The invention relates to buffers for railway vehicles. According to this invention, the spindle is made separately from the head and of a material having a greater tensile strength than that of which the head is composed, and the head and spindle are so formed that the spindle can be readily inserted from the front end and secured in position in the head. A is the buffer head, B the plunger, C the casing, D the spindle, E a spring surrounding the spindle D and held at the



rear end by an abutment F secured to the base of the casing C and at the front end by a collar or washer G secured to the spindle D, or by a projection of the buffer head. The rear end of the spindle passes through the headstock H and is provided in known manner with a nut K, spring washers L and a collar M. A hole is formed in the buffer head to receive the conical head I of the spindle, which may be flush with the head or recessed therein. The spindle D is secured to the head A by a small split steel ring inserted in a groove formed in the spindle. This ring is easily cut by a chisel if it is desired to remove the spindle from the head. (*Accepted July* 23, 1919.)

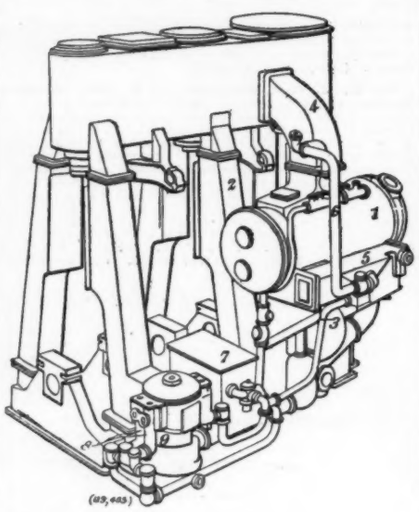
129,084. J. Mitchell, Putney, London, and A. B. C. Coupler, Limited, London. Buffers. (6 *Figs.*) June 28, 1918.—The invention relates to buffers for railway vehicles of what is known as the barrel plunger type. According to the invention, the case consists of a cylindrical tube which can be bolted or riveted to an annular flange integral with the baseplate, or the tube may pass through the baseplate and the end be expanded over the opening of the baseplate, or the annular flange may be shrunk on to the tubular casing. In Fig. 1 an



annular flange C is provided integral with the baseplate B and the case A is either riveted or bolted to the flange. In Fig. 2 the annular flange C is shrunk on to the case A and the parts may also be riveted or bolted together. In Fig. 3 the case A is shown as passing through the flanged baseplate, the inner end of the tube being expanded over the opening in the baseplate. In Fig. 4 an angle ring F is shown riveted to the case A and the baseplate B; the rivets may be replaced by bolts and nuts or the ring may be welded to the base plate. (*Accepted July* 16, 1919.)

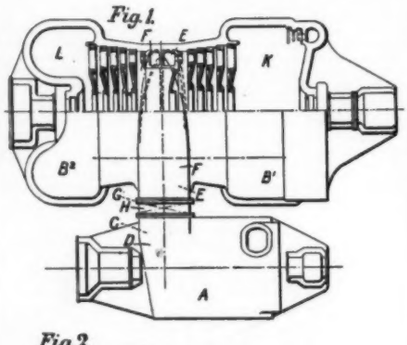
STEAM ENGINES, BOILERS, EVAPORATORS, &c.

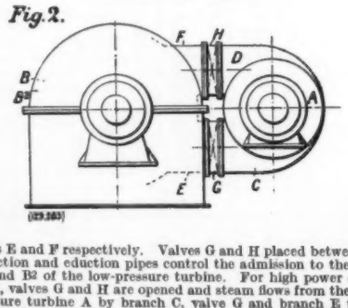
129,405. D. B. Morison, Hartlepool. Steam Engine Construction. (1 *Fig.*) June 7, 1918.—This invention relates to improvements in steam engine construction with particular reference to reciprocating marine condensing engines. The invention consists in a particular construction and arrangement of the main condenser for condensing steam from the main propelling engines relative to the auxiliary condenser for independently condensing steam from the auxiliary engines. The primary feature of this special construction is the embodiment in the engine structure of both the main and auxiliary condensers in definite relative positions. 1 designates the main condenser which is supported on two of the back columns 2 of the engine structure by means of brackets 3, the exhaust steam from the low pressure cylinder of the main engines passing to the condenser 1 by the pipe 4. 5 designates the auxiliary condenser to which exhaust steam from the auxiliary engines passes by way of the pipe 6. The water heads of both condensers are therefore in close proximity to each other whereby the connections are short, direct and simple—the valves are concentrated and easy of manipulation—and being elements of one structure the various parts can be standardised and greater utility obtained by economy in weight, in space occupied, in labour during manufacture and in labour during operation. The engine bed plate is



utilised for carrying a filter 7, and it will be seen that by this means the whole of the valves and connections between the auxiliary condenser and the filter are of definite sizes and relative dispositions. Further, the feed pumps 8 and the air pump 9 are definitely located with respect to the engine bed plate and to each other. Thus it is possible to standardise all these parts and fitments. This will be apparent upon reference to the drawing which shows the various pipes and connections *in situ*, and it will be clear that for a given size of engine all these various fitments can be of standard form. (*Accepted July* 23, 1919.)

129, 583. H. E. Yarrow, Scotstoun, Glasgow. Double Flow Steam Turbines. (2 *Figs.*) February 8, 1919.—The invention relates to low-pressure turbines of the double flow type divided into two sections in which steam from a high pressure turbine can be admitted into one or both sections according to the load. According to the invention, the design of such an installation is simplified and space saved, by making both sections of the low pressure turbine of the same size, admitting steam to the centre of the adjacent sections and providing similar exhaust chambers at the ends of the sections. Steam is led by eduction pipes C and D from the high pressure turbine A and enters the two parts B1, B2 of the low-pressure turbine by the induction





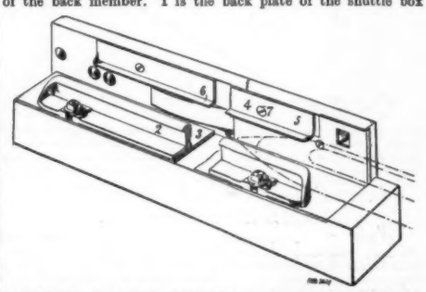
pipes E and F respectively. Valves G and H placed between the induction and eduction pipes control the admission to the parts B1 and B2 of the low-pressure turbine. For high power conditions, valves G and H are opened and steam flows from the high-pressure turbine A by branch C, valve G and branch E to B1, exhausting at K, and by branch D, valve H and branch F to B2, exhausting at L. For low power conditions, only one of the valves G and H is open. If valve G be open and valve H closed, steam flows from the high-pressure turbine A by branch C, valve G and branch E to B1, while the other portion B2 of the double flow turbine revolves idly in a vacuum. One of the two valves G and H may be omitted so as to leave a free passage through one of the eduction pipes. (*Accepted July* 23, 1919.)

127,997. Sir G. A. Muntz, Stratford-on-Avon. A Liquid Fuel Burner. (4 *Figs.*) June 13, 1918.—This invention refers to an improved liquid fuel burner for furnaces fired by liquid fuel of the type in which a whirling motion is imparted to the atomised fuel before it leaves the burner and an atomising chamber is provided between the means for imparting the whirling motion to the atomised fuel and the spray outlet or nozzle. In accordance with the improvements, the fuel burner comprises a body or pipe *c* terminating in a nozzle or cap *d* with a central aperture or apertures for the liquid or vapour outlet. Into the body or pipe *c* a plug *e* is screwed in a manner permitting adjustment of its position. The plug has on its periphery a series of

grooves *f*, or it may have a series of holes through it, and the grooves or holes are inclined or curved with respect to the axis of the plug. Beyond the plug and between it and the nozzle outlet is a considerable space or chamber into which the oil inlet pipe *a* is connected at the end adjacent to the plug, and preferably from this chamber a blow-off pipe *g* for the removal of dirt or the like is provided closed by a suitable cock. The compressed air or steam is admitted to the burner through the similarly inclined passages *f* of the plug so that a whirling motion is imparted to it as it enters the atomising chamber where it picks up and atomises the liquid fuel, the whirling motion of the atomised fuel ensuring effective mixture, and after atomisation of the fuel the mixture is forced out at the nozzle. (*Accepted June* 25, 1919.)

TEXTILE MACHINERY.

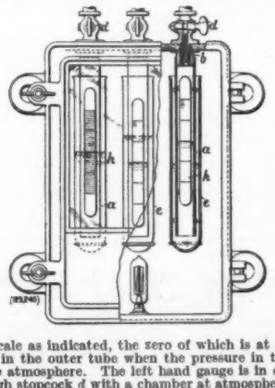
128,363. A. Newton-Smith, Westminster, London. Shuttle Boxes. (1 *Fig.*) June 14, 1918.—This invention has relation to what is known as the screed which, in carrying out this invention, is made of a metal plate stamped or pressed to shape. In accordance with this invention, the screed is of L-shape in section and comprises a back member, wholly in one plane, and having, at its lower end, a horizontal flange, the ends of which are curved or bent to join with and form continuations of the vertical edges of the back member. 1 is the back plate of the shuttle box



and 2 is the front plate, adjustable, as usual, on the flyplate 3. 4 is the metal screed which, in accordance with this invention, is of L-shape, in section and comprises a back member 5, wholly in one plane, having at its lower end a horizontal flange 6, the ends of which are curved or bent to join with, and form continuations of the vertical edges of the back member 5. The back member 5 is secured to the back plate 1 by screws 7, the heads of which do not project beyond the face thereof. The screed by providing slots for the screws 7, may be adjusted vertically. (*Accepted July* 2, 1919.)

MISCELLANEOUS.

129,245. E. W. Robey, London. Pressure Gauges. (2 *Figs.*) April 9, 1919.—It is desirable that a pressure gauge of the kind in which the pressure is read on a scale as the difference of level of two columns of liquid should be independent of variation in the amount of liquid in the gauge. A gauge, according to the present invention, consists of an outer tube closed at its lower end and containing the liquid, and an inner tube open at each end and communicating at its upper end with the source of pressure. The float is in the inner tube. The open ended glass tube *a* is supported by a cork *b* bored to receive the tube of a three-way cock *d*. The outer glass tube *e* is supported co-axially with the inner tube. The float *h* in the inner tube



carries a scale as indicated, the zero of which is at the level of the liquid in the outer tube when the pressure in the gauge is that of the atmosphere. The left hand gauge is in communication through stopcock *d* with a chamber at atmospheric pressure so that the level of the liquid in tubes *a* and *e* is the same, namely, the zero of the scale. The middle gauge is in communication with a chamber at a pressure above atmospheric, and the right-hand gauge with a chamber at a pressure below atmospheric; the pressure is read directly on the scale, in the former case above the zero, and in the latter case below the zero, by noting the mark on the scale level with the meniscus in the outer tube. (*Accepted July* 16, 1919.)